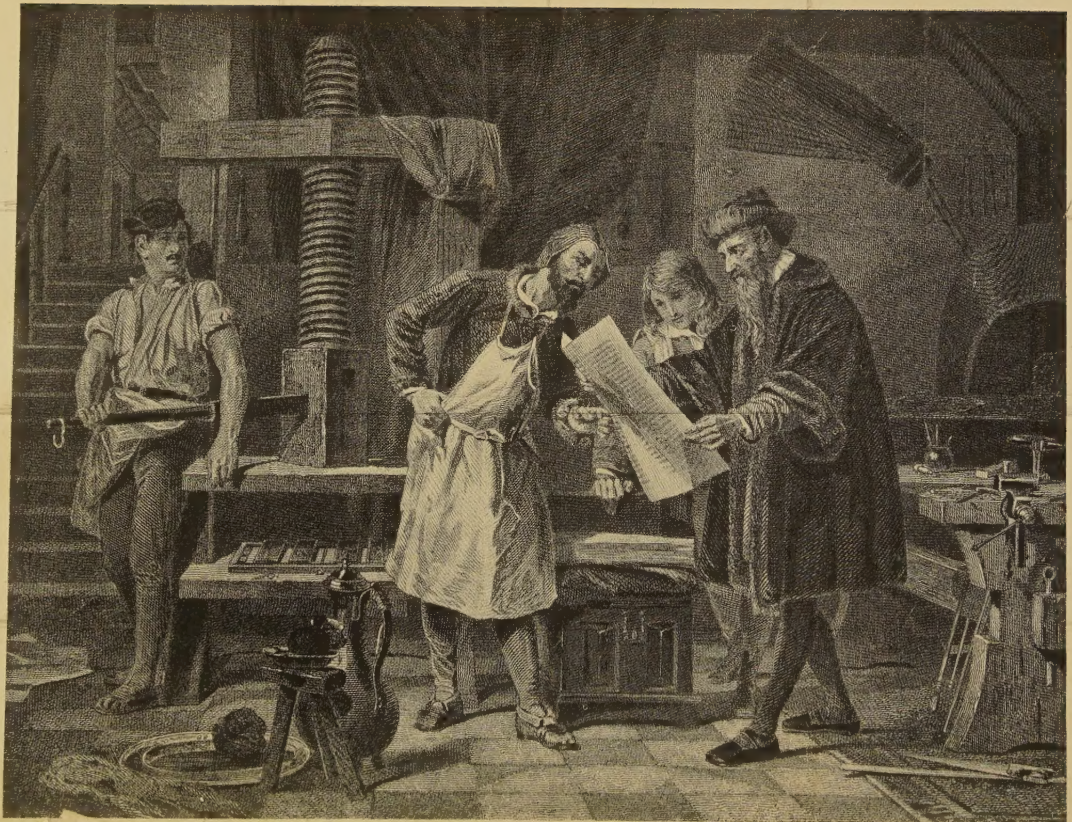

Gutenberg Takes the First Proof

Historic Inventions

By
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To

J. W. H.

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I

GUTENBERG AND THE PRINTING PRESS
About 1400–1468

THE free cities of mediæval Germany were continually torn asunder by petty civil wars. The nobles, who despised commerce, and the burghers, who lived by it, were always fighting for the upper hand, and the laboring people sided now with one party, and now with the other. After each uprising the victors usually banished a great number of the defeated faction from the city. So it happened that John Gutenberg, a young man of good family, who had been born in Mainz about 1400, was outlawed from his home, and went with his wife Anna to live in the city of Strasburg, which was some sixty miles distant from Mainz. He chose the trade of a lapidary, or polisher of precious stones, an art which in that age was held in almost as high esteem as that of the painter or sculptor. He had been well educated, and his skill in cutting gems, as well as his general learning and his interest in all manner of inventions, drew people of the highest standing to his little workshop, which was the front room of his dwelling house.

One evening after supper, as Gutenberg and his wife were sitting in the room behind the shop, he chanced to pick up a playing-card. He studied it very carefully, as though it were new to him. Presently

his wife looked up from her sewing, and noticed how much absorbed he was. "Prithee, John, what marvel dost thou find in that card?" said she. "One would think it the face of a saint, so closely dost thou regard it."

"Nay, Anna," he answered thoughtfully, "but didst thou ever consider how the picture on this card was made?"

"I suppose it was drawn in outline, and then painted, as other pictures are."

"But there is a better way," said Gutenberg, still studying the playing-card. "These lines were first marked out on a wooden block, and then the wood was cut away on each side of them, so that they were left raised. The lines were then smeared with ink and pressed on the cardboard. This way is shorter, Anna, than by drawing and painting each picture separately, because when the block is once engraved it can be used to mark any number of cards."

Anna took the playing-card from her husband's hand. It represented a figure that was known as the Knave of Bells. "It's an unsightly creature," she said, studying it, "and not to be compared with our picture of good St. Christopher on the wall yonder. Surely that was made with a pen?"

"Nay, it was made from an engraved block, just like this card," said the young lapidary.

"St. Christopher made in that way!" exclaimed his wife. "Then what a splendid art it must be, if it keeps the pictures of the blessed saints for us!"

The picture of the saint was a curious colored wood-

cut, showing St. Christopher carrying the child Jesus across the water. Under it was an inscription in Latin, and the date 1423.

"Yes, thou art right, dear," Gutenberg went on. "Pictures like that are much to be prized, for they fill to some extent the place of books, which are so rare and cost so much. But there are much more valuable pictures in the Cathedral here at Strasburg. Dost thou remember the jewels the Abbot gave me to polish for him? When I carried them back, he took me into the Cathedral library, and showed me several books filled with these engraved pictures, and they were much finer than our St. Christopher. The books I remember were the 'Ars Memorandi,' the 'Ars Moriendi,' and the 'Biblia Pauperum,' and the last had no less than forty pictures, with written explanations underneath."

"That is truly wonderful, John! And what are they about?"

"The 'Biblia Pauperum' means 'Bible for the Poor,' and is a series of scenes from the Old and New Testaments."

"I think I've heard of it; but I wish you'd tell me more about it."

John leaned forward, his keen face showing unusual interest. "The forty pictures in it were made by pressing engraved blocks of wood on paper, just like the St. Christopher, or this playing-card. The lines are all brown, and the pictures are placed opposite each other, with their blank backs pasted together, so they form one strong leaf."

"And how big are the pictures?

"They are ten inches high and seven or eight inches wide, and each is made up of three small pictures, separated by lines. More than that, there are four half-length figures of prophets, two above and two below the larger pictures. Then there are Latin legends and rhymes at the bottom of each page."

"And all that is cut on wood first?" said Anna, doubtfully. "It sounds almost like a miracle."

"Aye. I looked very closely, and the whole book is made from blocks, like the playing-card."

"Art thou sure it's not the pencraft of some skilful scribe?"

"Assuredly I am. Dost thou see, Anna, how much better these blocks are than the slower way of copying by hand? When they're once cut many books can be printed as easily as one."

"Aye," answered his wife, "and they will be cheaper than the works written out by the scribes, and still be so costly that whoever can make them ought to grow rich from the sale. If thou canst do it, it will make thy fortune. Thou art so ingenious. Canst thou not make a 'Bible for the Poor'?"

"Little wife, thou must be dreaming!" But John Gutenberg smiled, for he saw that she had discovered the thought that had been in his mind.

"But couldst thou not?" Anna persisted. "Thou art so good at inventing better ways of doing things."

Gutenberg laughed and shook his head. "I have found new ways to polish stones and mirrors," said

he, "but those are in my line of work. This is quite outside it, and much more difficult."

Nothing more was said on the subject that night, but Anna could see, as day followed day, that her husband was planning something, and she felt very certain that he was thinking out a way of making books more quickly than by the old process of copying them word for word by hand.

A few weeks later the young lapidary surprised his wife by showing her a pile of playing-cards. "See my handicraft," said he. "Aren't these as good as the Knave of Bells I gave thee?"

She looked at them, delight in her eyes. "They are very much better, John. The lines are much clearer, and the color brighter."

"Still, that is only a step. It is of little use unless I can cut letters, and press them on vellum as I did these cards. I shall try thy name, Anna, and see if I cannot engrave it here on wood."

He took a small wooden tablet from the work-table in his shop, and marking certain lines upon it, cut away the wood so that it left a stamp of his wife's name. Brushing ink over the raised letters he pressed the wood upon a sheet of paper, and then, lifting it carefully, showed her her own name printed upon the paper.

"Wonderful!" she cried. "The letters have the very likeness of writing!"

"Aye," agreed Gutenberg, looking at the four letters, "it is not a failure. I think with patience and perseverance I could even impress a copy of our picture of St. Christopher. It must have been made from some

manner of engraved block. See." He took the rude print from the wall, and showed her on the back of it the marks of the stylus, or burnisher, by which it had been rubbed upon the wood. "Thou mayst be sure from this that these lines were not produced by a pen, as in ordinary writing," said he.

"Well," said Anna, "it would surely be a pious act to multiply pictures of the holy St. Christopher."

Encouraged by his wife's great interest, and spurred on by the passion for invention, Gutenberg now set himself seriously to study the problem of engraving. First of all he found it very difficult to find the right kind of wood. Some kinds were too soft and porous, others were liable to split easily. Finally he chose the wood of the apple-tree, which had a fine grain, was dense and compact, and firm enough to stand the process of engraving. Another difficulty was the lack of proper tools; but he worked at these until his box was supplied with a stock of knives, saws, chisels, and gravers of many different patterns. Then he started to draw the portrait of the saint.

At his first attempt he made the picture and the inscription that went with it on the same block, but as soon as he had finished it a better idea occurred to him. The second time he drew the picture and the inscription on separate blocks. "That's an improvement," he said to his wife, "for I can draw the picture and the letters better separately, and if I want I can use different colored inks for printing the two parts." Then he cut the wood away from the drawings, and inking them, pressed them upon the paper. The result was a

much clearer picture than the old "St. Christopher" had been.

He studied his work with care. "So far so good," said he, "but it's not yet perfect. The picture can't be properly printed without thicker ink. This flows too easily, and even using the greatest care I can hardly keep from blotting it."

He had to make a great many experiments to solve this difficulty of the ink. At last he found that a preparation of oil was best. He could vary the color according to the substances he used with this. Umber gave him lines of a darkish brown color, lampblack and oil gave him black ink. At first he used the umber chiefly, in imitation of the old drawings that he was copying.

When his ink was ready he turned again to his interested wife. "Now thou canst help me," said he. "Stuff and sew this piece of sheepskin for me, while I get the paper ready for the printing."

Anna had soon done as he asked. Then Gutenberg added a handle to the stuffed ball. "I need this to spread the ink evenly upon the block," said he. "One more servant of my new art is ready."

He had ground the ink upon a slab. Now he dipped his printer's dabber in it, and spread the ink over the wood. Then he laid the paper on it, and pressed it down with the polished handle of one of his new graving tools. He lifted it carefully. The picture was a great improvement over his first attempt. "This ink works spendidly!" he exclaimed in delight.

"Now I shall want a picture of St. Christopher in every room in the house," said Anna.

"But what shall I do?" said Gutenberg. "I can't afford the time and money to make these pictures, unless I can sell them in some way."

"And canst thou not do that?"

"I know of no way at present; but I will hang them on the wall of the shop, and perhaps some of my customers will see them and ask about them."

The young lapidary was poor, and he had spent part of his savings in working out his scheme of block-printing. He could give no more time to this now, but he hung several copies of the "St. Christopher" in his front room. Several days later a young woman, stopping at Gutenberg's shop for her dowry jewels, noticed the pictures. "What are those?" said she. "The good saint would look well on our wall at home. If thou wilt wrap the picture up and let me take it home I will show it to my husband, and if he approves I will send thee the price of it to-morrow."

Gutenberg consented, and the next day the woman sent the money for the "St. Christopher." A few days later it happened that several people, calling at the shop to buy gems, chose to purchase pictures instead. Anna was very much pleased by the sales, and told her husband so at supper that evening. But he was less satisfied. "In spite of the sales I have lost money to-day," said he. "Those who bought the prints had meant to buy jewels and mirrors, and if they had done so I should have made a bigger profit. The pictures take people's attention from the gems, and so hurt my business."

"But may it not be that the printing will pay thee

better than the sale of jewels, if thou wilt keep on with it?" suggested the hopeful wife. "How soon shalt thou go to the Cathedral with the Abbot's jewels?"

"As soon as I have finished the polishing. Engraving these blocks has kept me back even in that."

"When thou dost go take some of thy prints with thee," begged Anna, "and see what the Father has to say about them."

By working hard Gutenberg had the Abbot's jewels finished two days later, and he took them with several of his prints to the Cathedral. He was shown into the library, where often a score of monks were busied in making copies of old manuscripts. He delivered the jewels to the Abbot, and then showed him the pictures.

"Whose handiwork is this?" asked the Father.

But Gutenberg was not quite ready to give away his secret, and so he answered evasively, "The name of the artisan does not appear."

"Where didst thou obtain them?" asked the Abbot.

"I pray thee let me keep that also a secret," answered Gutenberg.

The Abbot looked them over carefully. "I will take them all," said he. "They will grace the walls of our library, and tend to preserve us from evil."

The young jeweler was very much pleased, and hurried home to tell his wife what had happened. She was delighted. "Now thou art in a fair way to grow rich," said she.

But Gutenberg was by nature cautious. "We mustn't forget," he answered, "that the steady income

of a regular trade is safer to rely on than occasional success in other lines."

A few days later a young man named Andrew Dritzhn called at Gutenberg's shop, and asked if he might come and learn the lapidary's trade. Theretofore Gutenberg had had no assistants, but, on thinking the matter over, he decided that if he had a good workman with him he would have more time to study the art of printing. So he engaged Dritzhn. Soon after this the new apprentice introduced two young friends of his, who also begged for the chance to learn how to cut gems and set them, and how to polish Venetian glass for mirrors and frame them in carved and decorated copper frames. Gutenberg agreed and these two others, named Hielman and Riffe, came to work with him.

The shop was now very busy, with the three apprentices and the master workman all occupied. But Gutenberg was anxious to keep his new project secret, and so he fitted up the little back room as a shop, and spent his evenings working there with Anna.

On his next visit to the Cathedral he came home with a big package under his arm. He unwrapped it, and showed Anna a large volume. "See," said he, "this is the 'History of St. John the Evangelist.' The Abbot gave it to me in return for some more copies of my St. Christopher. It is written on vellum with a pen, and all the initial letters are illuminated. There are sixty-three pages, and some patient monk has spent months, aye, perhaps years, in making it. But I have a plan to engrave it all, just as I did the picture."

"Engrave a whole book! That would be a miracle!"

"I believe I can do it. And when once the sixty-three blocks are cut, a block to a page, I can print a score of the books as easily as one copy."

"Then thou canst sell books as well as the monks! And when the blocks are done it may not take more than a day to make a book, instead of months and years."

So John Gutenburg set to work with new enthusiasm. He needed a very quiet place in which to carry out his scheme, and more room than he had at home. It is said he found such a place in the ruined cloisters of the Monastery of St. Arbogast in the suburbs of Strasburg. Thither he stole away whenever he could leave the shop, and not even Anna went with him, nor even to her did he tell what he was doing. At last he brought home the tools he had been making, and started to cut the letters of the first pages of the "History of St. John." Night after night he worked at it, until a great pile of engraved blocks was done.

Then one evening there was a knock at the door of the living-room, and before he could answer it the door was opened, and the two apprentices, Dritzhn and Hielman, came in. They saw their master bending over wooden blocks, a pile of tools, and the open pages of the History. "What is this?" exclaimed Dritzhn. "Some new mystery?"

"I cannot explain now," said the confused inventor.

"But thou promised to teach us all thy arts for the money we pay thee," objected Hielman, who was of an avaricious turn of mind.

"No, only the trade of cutting gems and shaping mirrors."

"We understood we paid thee for all thy teaching," objected the apprentice. "'Tis only fair we should have our money's worth."

Gutenberg thought a moment. "This work must be done in quiet," said he, "and must be kept an absolute secret for a time. But I do need money to carry it on rightly."

This made Dritzhn more eager than ever to learn what the work was. "We can keep thy secret," said he, "furnish funds, and perhaps help in the business."

Gutenberg had misgivings as to the wisdom of increasing his confidants, but he finally decided to trust them. First he pledged each to absolute secrecy. Then he produced his wooden cuts, and explained in detail how he had made them. Both the apprentices showed the greatest interest. "Being a draughtsman, I can help with the figures," said Dritzhn.

"Yes," agreed Gutenberg, "but just now I am chiefly busy in cutting blocks for books."

"Books!" exclaimed the apprentice.

"Yes. I have found a new way of imprinting them." Then he showed them what he was doing with the History.

Dritzhn was amazed. "There should be a fortune in this!" said he. "But will not this art do away with the old method of copying?"

"In time it may," agreed the inventor. "That's one reason why we must keep it secret. Other-

wise the copyists might try to destroy what I have done."

As a result of this interview a contract was drawn up between Gutenberg and his apprentices, according to the terms of which each apprentice was to pay the inventor two hundred and fifty florins. The work was to be kept absolutely secret, and in case any of the partners should die during the term of the agreement the survivors should keep the business entirely to themselves, on payment of one hundred florins to the heirs of the deceased partner. Riffe, the third apprentice, was admitted to the business, and after that the four took turns looking after the jewelry shop and working over the blocks for the History.

But the pupils were not so well educated as the master. They could not read, and had to be taught how to draw the different letters. They were clumsy in cutting the lines, and spoiled block after block. Gutenberg was very patient with them. Again and again he would throw away a spoiled block and show them how the letters should be cut properly.

In time the blocks were all finished. "Now I can help," said Anna. "Thou must let me take the impressions."

"So thou shalt," her husband answered. "To-night we will fold and cut the paper into the right size for the pages, and grind the umber for ink. To-morrow we will begin to print the leaves."

The following day they all took turns making the impressions. Page after page came out clear and true. Then Anna started to paste the blank sides of the sheets

together, for the pages were only printed on one side. In a week a pile of the Histories was printed and bound, and ready to be sold.

The jewelers had little time to offer the books to the wealthy people of the city, and so Gutenberg engaged a young student at the Cathedral, Peter Schœffer by name, to work for him. The first week he sold two copies, and one other was sold from the shop. That made a good beginning, but after that it was more difficult to find buyers, and the firm began to grow doubtful of their venture.

The poor people of Strasburg could not read, and could not have afforded to buy the books in any event, the nobility were hard to reach, and the clergy, who made up the reading class of the age, were used to copying such manuscripts as they needed. But this situation did not prevent Gutenberg from continuing with his work. He knew that the young men who were studying at the Cathedral had to copy out word for word the "Donatus," or manual of grammar they were required to learn. So the firm set to work to cut blocks and print copies of this book. When they were finished they sold more readily than the History had done, and the edition of fifty copies was soon disposed of. But by that time all the scholars of the city were supplied, and it was very difficult to send the books to other cities. There were no newspapers, and no means of advertising, and the only practical method of sale was to show the book to possible purchasers, and point out its merits to them. So Gutenberg turned to two other books that were used by the monks, and printed them.

One was called the "Ars Memorandi," or "Art of Remembering," and the other the "Ars Moriendi," or "Art of Knowing How to Die."

Whenever he printed a new book Gutenberg took it to the Cathedral to show the priests. He carried the "Ars Moriendi" there, and found the Abbot in the library, looking over the manuscripts of several monks.

"Good-morning, my son," said the Abbot. "Hast thou brought us more of thy magical books?"

"It is not magic, Father; it is simply patience that has done it," said Gutenberg, handing the Abbot a copy of his latest book.

"Thanks, my son. It is always a pleasure to examine thy manuscripts."

The monks gathered around the Abbot to look at the new volume. "It is strange," said one of them, named Father Melchior. "How canst thou make so many books? Thou must have a great company of scribes."

Another was turning over the pages of the book. "It is not quite like the work of our hands," said he.

"It is certain that none of us can compete with thy speed in writing," went on Father Melchior. "Every few weeks thou dost bring in twelve or more books, written in half the time it takes our quickest scribe to make a single copy."

"Moreover," said another, "the letters are all so exact and regular. Thou hast brought two copies, and one has just as many letters and words on a page as the other, and all the letters are exactly alike."

The Abbot had been studying the book closely.

Now he asked the monks to withdraw. When Gutenberg and he were alone, he said, "Are these books really made with a copyist's pen?" He cast a searching glance at the lapidary.

Gutenberg, much embarrassed, had no answer for him.

"It is as I guessed," said the Abbot. "They are made from blocks, like the St. Christopher."

The Abbot smiled at the look of dismay on Gutenberg's face. "Have no fear," he added. "It may be that I can supply thee with better work for thy skill. We need more copies of the 'Biblia Pauperum' for our use here, and I have no doubt thou couldst greatly improve on the best we have."

"I should like to do it," said Gutenberg, "if there were not too much expense."

"The priests will need many copies," the Abbot assured him. "And thou shalt be well paid for them."

So the young printer agreed to undertake this new commission. It meant much to him to have secured the patronage of the Abbot, for this would set a seal upon the excellence of his work, and bring him to the notice of the wealthy and cultivated people of the day.

Gutenberg took the Abbot's copy of the "Biblia" home, and he and the apprentices started work upon the wooden blocks. There were many cuts in the book which had to be copied, and so they engaged two wood engravers who lived in Strasburg to help them. Even so, it took them months to finish the book. But when it was printed and bound, and a copy shown to the Abbot, he was delighted with it. "Thou hast done

nobly, my son," said he, " and thy labors will serve the interests of our Mother Church. Thou shalt be well paid."

Gutenberg returned home with the money, and showed it delightedly to his wife. "I knew thou wouldst triumph," said she. "Only to think of a real 'Biblia Pauperum' made by my John Gutenberg. We shall see wonderful days!"

Now fortune grew more favorable. The "Biblia" sold better than the other books had done, and they next printed the Canticles, or Solomon's Song. This was impressed, as the others had been, on only one side of the page, and from engraved wooden blocks. Then Gutenberg thought he would like to print the entire Bible. Anna favored this, and he started to figure out how long the work would take.

"There are seven hundred pages in the Bible," said he. "I cannot engrave more than two pages a month working steadily, and at such a rate it would take me fully three hundred and fifty months, or nearly thirty years, to make blocks enough to print the Holy Book."

"Why, thou wouldst be an old man before it was done!" cried his wife in dismay.

"Yes, and more than that, this process of engraving is dimming to the eyes. I should be blind before my work was half done."

"But couldst thou not divide the work with the others?"

"Yes, if only I could persuade them to attempt so big a work. They want to try smaller books, for they say my new process is hardly better for making a large

book than the old method of copying. It may be that I can get them to print the Gospels gradually, one book at a time."

Though the workmen were now growing more weary and disheartened with each new volume they undertook, Gutenberg would not give up. He persuaded them to start cutting the blocks for the Gospel of St. Matthew. But as he worked with his knives the apprentices grumbled about him. At last he had the first block nearly done. Then his hand slipped, the tool twisted, and the block was split across.

The other men looked aghast. So much work had gone for nothing.

Gutenberg sat studying the broken block of wood. As he studied it a new idea came to him. Picking up his knife he split the wood, making separate pieces of every letter carved on it. Then he stared at the pile of little pieces that lay before him like a bundle of splinters. He realized that he was now on the trail of a greater discovery than any he had yet made, for these separate letters could be used over and over again, not only in printing one book but in printing hundreds.

Taking a fresh block he split it into little strips, and cutting these down to the right size, he carved a letter on the end of each strip. This was more difficult than cutting on the solid block, and he spoiled many strips of wood before he got a letter that satisfied him. But finally he had made one, and then another, and another, until he had all the letters of the alphabet. He was careful to cut the sticks of the proper width, so that the letters would not be too far apart when they should be

used for printing. When they were done he showed them to the others and called them *stucke*, or type. They soon saw what a great step forward he had made.

The first words he printed with type were *Bonus homo*, "a good man." He took the letters that spelled the first word, and putting them in their proper order tied them together with a string. He only had one letter o, so he had to stop and cut two more. Then he made a supply of each letter of the alphabet, and put type of each letter separately in little boxes, to keep them from getting mixed. So he made the first font of movable type known to history.

As he experimented with these first type he made another improvement. He found it was hard to keep the letters tight together, so that he could ink them and print from them. He cut little notches in the edges of the different type, and by fastening his linen thread about the notches in the outside letters of each word he found that he could hold a word as tightly together as if all the letters in it were cut on a single block.

The cutting of the type and the studying out of new and better ways of holding them together took a great deal of time, and meanwhile the sales of gems and mirrors had fallen off. The apprentices had not the master's skill in holding the letters together, and they grew discouraged as time after time the type would separate as they were ready to print from it. They wanted to go back to the blocks, but Gutenberg insisted that his new way was the better. At last he hit upon another idea. He would make a press which

would hold the type together better than a linen thread or a knot of wire.

After many patient experiments he finished a small model of a press which seemed to him to combine all the qualifications needed for his work. He took this to a skilful turner in wood and metal, who examined it carefully. "This is only a simple wine-press I am to make, Master John," said he.

"Yes," answered Gutenberg, "it is in effect a wine-press, but it shall shortly spout forth floods of the most abundant and marvelous liquor that has ever flowed to quench the thirst of man."

The mechanic, paying no heed to Gutenberg's excitement, made the press for him according to the model. It was set up in the printing-rooms of Dritzhn's dwelling, and the firm went on with their work of cutting movable type. But the sale of books was small, and for two years more the apprentices grumbled, and protested that they should have stuck to the lapidary's art.

New troubles soon arose. It was found that the ink softened the type and spoiled the form of the letters. "We must make more fresh type," said Gutenberg, "until we can find a way to harden the wood." Then a bill was sent in of one hundred florins for press-work. The partners were angry, and said they saw no real advantage in the press. "But without the frame and press all our labor of making *stucke* will prove useless," answered the inventor. "We must either give up the art, and disband, or make the necessary improvements as they are called for."

Gutenberg was made of sterner stuff than his partner Dritzhn. Two years of small success and great doubt had told upon the latter, and so one day when Father Melchior of the Cathedral told him he noticed that he was worried, Dritzhn confessed to him the secret of the printing shop. "I have put money into the business," said he, "and if I leave now I fear I shall lose it all."

"Leave it by all means," advised the Father, "for be sure that no good will come of these strange arts."

But when he went back to the shop Dritzhn discovered the others setting type for a new work, a dictionary, that was called a "Catholicon." They were all enthusiastic about this, believing it would have a readier sale than their other works, and so he decided to stay with them a little longer, in spite of the Father's advice.

Just as the dictionary was ready to be issued, in the autumn of 1439, an event occurred which threw the firm into confusion. Dritzhn died suddenly, and his two brothers demanded that Gutenberg should let them take his place in the firm. He read over the contract which they had all signed, and then told them that they could not be admitted as partners, but should be paid the fifteen florins which the books showed were due to Dritzhn's heirs. They rejected this with scorn, and at once started a lawsuit against Gutenberg and his partners.

There were no such protections for inventions as patents then; rumor soon spread abroad the news that Gutenberg had discovered a new art that would prove a gold-mine, and the poor inventor saw that the law-

suit would probably end in his ruin. The printing-press had stood in Dritzhn's house, and before Gutenberg could prevent it the two brothers had stolen parts of it. Then he had what was left of it carried to his own house; but even here spies swarmed to try to learn something of his secret. Finally he realized that his invention was not safe even there, and decided that every vestige of his work must be destroyed. "Take the *stucke* from the forms," said he to his friends, "and break them up in my sight, that none of them may remain perfect."

"What, all our labor for the last three years!" cried Hielman.

"Never mind," answered Gutenberg. "Break them up, or some one will steal our art, and we shall be ruined."

So, taking hammers and mallets, they broke the precious forms of type into thousands of fragments.

The lawsuit dragged along, and finally ended in Gutenberg's favor. The firm was ordered to pay Dritzhn's brothers the fifteen florins, and nothing more. But the type were destroyed, and the partners were afraid to make new ones, lest the suspicious public should spy upon them and learn their secret. When the term of the contract between the partners came to an end it was not renewed. Each of the firm went his own way, and John Gutenberg opened his lapidary's shop again and tried to build up the trade he had lost.

His wife was still Gutenberg's chief encouragement. She was certain that some day he would win success, and often in the evening she would urge him not to

despair of his invention, but to wait till the time should be ripe for him to go on with it again. As a matter of fact it was impossible for him to give it up. Before long he was cutting *stucke* again in his spare hours, and then trying his hand at printing single pages.

He felt however that it would be impossible for him to resume his presswork in Strasburg. There was too much prejudice against his invention there. So he decided to go back to his home town of Mainz, where many of his family were living. Anna agreed with this decision, and so they closed their shop, sold their goods, and journeyed to his brother's home. There one day his brother introduced him to a rich goldsmith named Faust, and this man said he understood that Gutenberg had invented a new way of making books. John admitted this, and told him some details of his process.

The goldsmith was most enthusiastic, and suggested that he might be able to help the inventor with money. Gutenberg said he should need two or three thousand florins. "I will give it to thee," answered Faust, "if thou canst convince me that it will pay better than goldsmithing."

Then the printer confided all his secrets to Faust, and the latter considered them with great care. At last he was satisfied, and told Gutenberg that he would enter into partnership with him. "But where shall we start the work?" he added. "Secrecy is absolutely necessary. We must live in the house in which we work."

"I had thought of the Zum Jungen," answered Gu-

tenberg, naming an old house that overlooked the Rhine.

"The very place," agreed Faust. "It is almost a palace in size, and will give us ample room; it is in the city, and yet out of its bustle. It is vacant now, and I will rent it at once. When canst thou move there?"

"At once," said Gutenberg, more pleased than he dared show.

So the printer and his good wife moved to the Zum Jungen, which was more like a castle than a tradesman's dwelling-house. Its windows looked over the broad, beautiful river to the wooded shores beyond. Faust advanced Gutenberg the sum of 2,020 florins, taking a mortgage on his printing materials as security. Then Faust moved his family and servants to the old house, and the firm started work. Hanau, the valet of Gutenberg's father, and a young scholar named Martin Duttlinger, joined them at the outset.

Two well-lighted rooms on the second floor, so placed as to be inaccessible to visitors, were chosen for the workshops. Here the four worked from early morning until nearly midnight, cutting out new sets of type and preparing them for the presswork. They began by printing a new manual of grammar, an "Absies," or alphabetical table, and the "Doctrinale." All three of these it was thought would be of use to all who could read.

Soon Faust discovered the same defect in the type that the workmen at Strasburg had discovered. The wooden letters would soften when used, and soon lose their shape. He spoke to Gutenberg about it, and the

latter studied the problem. At length an idea occurred to him. He opened a drawer and took out a bit of metal. He cut a letter on the end of it. "There is the answer," said he. "We will make our type of lead. We can cut it, and ink cannot soften it as it does wood."

Faust was very much pleased. Now that he understood Gutenberg's invention he realized how great a thing it was destined to become, and was anxious to help its progress in every way he could. One day Gutenberg told him that they needed a good man to cut the designs for the engravings. "Dost thou know of one?" asked Faust. "Of only one," was the answer. "He is Peter Schœffer, a youth who helped me before. He is now a teacher of penmanship in Paris."

"We must send for him," said Faust.

So Gutenberg sent for Schœffer, and the printing staff was increased to five.

Schœffer had considerable reputation as a scholar, and soon after he had joined them Gutenberg asked him what he thought was the most important book in the world. Schœffer replied that he was not sufficiently learned to answer the question.

"But to the best of thy knowledge," persisted Gutenberg.

"I remember that when I was in the Cathedral school," said Schœffer, "Father Melchior showed us the Gothic Gospels, or Silver Book, and said that more art and expense had been spent on the Bible than on any other book he knew. I believe therefore that it is the most useful and important book in the world."

"So I believe," agreed Gutenberg, "and I intend to print it in the best style possible to my art."

"But what a tremendous undertaking, to print the whole Bible!" exclaimed Schœffer.

"Yes, a stupendous work," Gutenberg agreed. "And so I want to start upon it at once."

Schœffer was amazed when Gutenberg showed him the new press he had built at the Zum Jungen. He watched the master dab the type with ink, slide them under the platen, and having pressed it down, take out the printed page.

"It is wonderful!" said he. "How many impressions canst thou take from the press in a day?"

"About three hundred, working steadily."

"Then books will indeed multiply! What would the plodding copyists say to this!"

When they began printing with the lead type they soon found that the metal was too soft. The nicest skill had to be used in turning the screw of the press, and only Gutenberg seemed able to succeed with it. Schœffer suggested that they should try iron.

"We have," said Gutenberg, "but it pierced the paper so that it could not be used."

Schœffer was used to experimenting in metals, and the next day he brought to the workroom an alloy which he thought might serve. It was a mixture of regulus of antimony and lead. They tried it, and found it was precisely the right substance for their use. Gutenberg and Faust were both delighted, and very soon afterward made Peter Schœffer a partner in the firm.

They now started on the great work of printing the

Bible. Duttlinger was commissioned to buy a Bible to serve for his own use. This was brought in secret to the workrooms, and the partners inspected it carefully. They realized what a huge undertaking it would be to print such a long book, but nevertheless they set out to do it. Each man was allotted his share in the labor, and the work began.

The press Gutenberg was using was a very simple affair. Two upright posts were fastened together by crosspieces at top and bottom. In this frame a big iron screw was worked by means of a handle. A board was fastened beneath the screw, and the type, when inked and set in a wooden frame, were placed on this board. The printing paper was laid over the type, and the screw forced the platen, which was the board fixed to it, down upon the paper. Then the screw was raised by the handle, the platen was lifted with it, and the printed paper was ready to be taken out. The screw was worked up and down in a box, called a hose, and the board on which the type were set for the printing was actually a sort of sliding table. The frame or chase of type was fixed on this table, and when inked and with the paper laid in place, was slid under the platen, which was a smooth planed board. The screw was turned down, the platen was pressed against the sheet of paper, and the printing was done.

Each of the workers at the Zum Jungen suggested valuable changes and additions. Schœffer proved wonderfully adept at cutting type, and later at illuminating the initial letters that were needed. The copies we have of the books published by this first Mainz press

bear striking witness to the rare skill and taste Peter Schœffer showed in designing and coloring the large capital letters that were considered essential at that day.

The firm had by now prepared several hundred pounds' weight of metal type for the Bible, had discovered that a mixture of linseed oil and lampblack made the best ink, and had invented ink-dabbers made of skin stuffed with wool. Then it occurred to Schœffer that there must be some easier way of making type than by cutting it out by hand. After some study he found it, and the firm began taking casts of type in plaster moulds. But the success of this method seemed very doubtful at first, for it was hard to get a good impression of such small things as type in the soft plaster. Again Schœffer showed his skill. He planned the cutting of punches which would stamp the outline of the type upon the matrix. He cut matrices for the whole alphabet, and then showed the letters cast from them to Gutenberg and Faust.

"Are these letters cast in moulds?" exclaimed the astonished Faust.

"Yes," answered Schœffer.

"This is the greatest of all thy inventions then," said Faust. "Thou art beyond all question a great genius!"

With type cast in this new way the firm printed the first page of their Bible in the spring of 1450. The press worked to perfection, and when they removed the vellum sheet the printed letters were clear, beautifully formed, and ranged in perfect lines. So began the

printing of what was to become famous as the Mazarine Bible. But it was not until five years later, in 1455, that the book was finished.

The Bible was printed, but its cost had been great, and the returns from its sale were small. Faust was dissatisfied with Gutenberg, and took occasion to tell Schœffer one evening that he believed the firm would do better without the master. "Thou hast devised the ink, the forms for casting type, and the mixture of metals," he said. "These are almost all that has been invented. Gutenberg spent 4,000 florins before the Bible was half done, and I do not see how he can ever repay me the sums I have advanced."

Faust played upon young Schœffer's vanity, he praised him continually and disparaged Gutenberg, and finally persuaded him they would be better off without the latter. Peter Schœffer was, moreover, in love with Faust's daughter Christiane, and wished to marry her. This was another inducement for him to side with the rich goldsmith.

Then one day Faust asked Gutenberg blankly when he intended to repay him the money he had advanced. Gutenberg was surprised, and told him he had nothing but the small profits the firm was making.

"I will give thee thirty days to pay the debt," said Faust, "and if thou dost fail to pay within that time I shall take steps to collect it."

"But how am I to procure it? Wouldst thou ruin me?" cried Gutenberg.

"The money I must have, and if thou art honest thou wilt pay me," came the hard answer.

The month ended, and Gutenberg had not found the money. He protested and pleaded with Faust, but the latter was obdurate. He started a lawsuit at once to recover the sums he had expended, and judgment was given against Gutenberg, commanding that he should pay what he had borrowed, together with interest. Gutenberg could not do this, and so Faust took possession of all the presses, the type, and the copies of the Bible that were already printed.

Gutenberg knew that he was ruined. His wife tried to console him. "I am worse than penniless," said he. "My noble art is at an end. What I most feared has happened. They have stolen my invention, and I have nothing left."

Meantime Schœffer had married Faust's daughter, and the two men took up the printing business for themselves. Faust showed the Bibles to friends, and was advised to carry a supply of them to Paris. He went to that city, and at first met with great success. He sold the King a copy for seven hundred and fifty crowns, and private citizens copies at smaller prices. But soon word spread abroad that this stranger's stock was inexhaustible. "The more he sells the more he has for sale," said one priest. Then some one started the report that the stranger was in league with the devil, and soon a mob had broken into his lodgings and found his stock of Bibles. Faust was arrested on the charge of dealing in the black art, and was brought before the court. He now decided that he would have to tell of the printing press if he were to escape, and so he made a full confession. So great was the wonder

and admiration at the announcement of this new invention that he was at once released, loaded with honors, and soon after returned to Mainz with large profits from his trip.

But Gutenberg was not entirely left to despair. His brother Friele, who was well-to-do, came to his aid, and interested friends in starting John at work on his presses again. He missed Schœffer's discoveries as to ink and the casts for type, but although he had not the means to print another copy of the Bible, he contrived to print various other books which were bought by the clerical schools and the monasteries. After a time Faust, realizing perhaps that Gutenberg was in reality the inventor of the art which he was beginning to find so lucrative, came to him, and asked his forgiveness. He admitted that he had been unfair in the prosecution of the lawsuit, and urged Gutenberg to take his old place in their firm. But Gutenberg could not be persuaded, he preferred to work after his own fashion, and to be responsible only to himself.

For eight years he carried on the business of his new printing shop in the Zum Jungen, with his brother and Conrad Humery, Syndic of Mainz, to share the expenses and profits. Then his wife, Anna, died, and he could not keep on with the work. His brother advised him to leave Mainz for a time and travel. So he sold his presses and type to the Syndic, and left Mainz. Wherever he journeyed he was received with honor, for it was now widely known that he had invented the new art of printing. The Elector Adolphus of Nassau invited him to enter his service as one of his gentlemen pension-

ers, and paid him a generous salary. Thus he was able to live in peace and comfort until his death in 1468.

Meanwhile Faust and Schœffer had continued to print the Bible and other works, and had found a prosperous market in France and the German cities. Schœffer cast a font of Greek type, and used this in printing a copy of Cicero's "De Officiis," which was eagerly bought by the professors and students of the great University of Paris. But as Faust was disposing of the last copies of this book in the French capital he was seized with the plague, and died almost immediately. For thirty-six years Peter Schœffer continued printing books, making many improvements, and bringing out better and better editions of the Bible.

The capture of Mainz in 1462 by the Elector Adolphus of Nassau gave the secrets of the printing press to the civilized world. Presses were set up in Hamburg, Cologne, Strasburg, and Augsburg, two of Faust's former workmen began printing in Paris, and the Italian cities of Florence and Venice eagerly took up the new work. Between 1470 and 1480 twelve hundred and ninety-seven books were printed in Italy alone, an indication of what men thought of the value of Gutenberg's invention.

William Caxton, an English merchant, learned the new art while he was traveling in Germany, and when he returned home started a press at Westminster with a partner named Wynken de Worde. This was the first English press, but others were quickly set up at Oxford and York, Canterbury, Worcester, and Norwich, and books began to appear in a steady stream.

The art of printing has seen great changes since Gutenberg's day. The type is now made by machinery, inked by machinery, set and distributed again by machinery. The letters, when once set up, are cast in plates of entire pages, so that they can be kept for use whenever they are wanted. Stereotyping and electrotyping have made this possible. The Mergenthaler Linotype machine sets and casts type in the form of solid lines. The great presses of to-day can accomplish more in twelve hours than the presses of 1480 in as many months.

But the great press we have is the direct descendant of the little one that John Gutenberg built in the Zum Jungen at Mainz, and the letters we read on the printed page are after all only another form of those he cut out with so much patient labor on his wooden blocks in Strasburg. Printing is one of the greatest inventions the world has ever seen, but it had its beginning in the simple fact that a young German polisher of gems fell to wondering how a rude playing-card had been made.

II

PALISSY AND HIS ENAMEL

About 1510-1589

THE discovery of a long-sought enamel and the successful manufacture of a new and beautiful type of pottery can scarcely be ranked among the great inventions of history, but the story of Bernard Palissy is far too interesting to need any such excuse. He was a worker in the fine arts, in a day when objects of beauty were considered of the first importance, and his success was then regarded as almost as great a thing as the building of the first McCormick reaper in another age.

This maker of a new and beautiful porcelain was a Frenchman, born about 1510 at the little village of La Chapelle Biron, which lies between the Lot and Dordogne, in Perigord. His parents were poor peasants, without the means or the opportunity to give Bernard much of a schooling, but he picked up a very fair knowledge of reading and writing, and kept his eyes so wide open that he learned much more than the average country boy. It was the age when the churches of France were being made glorious with windows of many-colored glass, and Bernard, watching the glass-workers, dared to ask if they would take him as apprentice. One of them would, and so the boy of Perigord began his career of artist, his field covering not only the manufacture of glass, but its cutting, arrang-

ing, and sometimes its painting for the rose-windows of the Gothic churches. And so skilled were those glass-workers and so deeply in love with their art that their glass has been the despair of the later centuries that have tried to copy them.

Like a true artist he was very much in earnest. With his spare time and such money as he could save he studied all subjects that seemed apt to be of help to him. He learned geometry, and drawing, painting, and modeling. In his desire for the greatest subjects for his windows and the finest treatment of them, Bernard turned to Italy, the home of the great painters, and copied their works. This led his eager mind to delve into Italian literature, and shortly the young workman was not only draughtsman and artist, but something of a man of letters as well. The little village of La Chapelle Biron found that the peasant's son, without any education in the church schools, was already a man of many talents and quite remarkable learning.

He had mastered his profession, and the town in Perigord was somewhat too small for him. He must see something of that outer world where many others were making works of art. His skill as a painter of glass, as a draughtsman, and land-measurer, would earn him a living wherever he might go. So he set forth on his travels, as many young scholars and artisans were used to do in those days, working here and there, collecting new ideas, talking with many men of different minds, and gaining a first-hand knowledge of the world that lay about him. He visited the chief

provinces of France, saw something of Burgundy and Flanders, and stayed for a time on the banks of the Rhine. His love of acquiring knowledge grew as he traveled, and he studied natural history, geology and chemistry. Where churches were being built he painted glass, where towns or nobles needed measurers or surveyors of their lands he worked for them. When he had seen as much of the world as he wished, he went to the town of Saintes, married, and settled there as a man of several trades.

It was in 1539 that Palissy became a citizen of Saintes, and several years later that chance sent his way a beautiful cup of enameled pottery. Some have said that the cup came from Italy, and some from Nuremberg, but it was of a new pattern to Palissy, and the more he looked at it and handled it the more he wanted to learn the secret of its making, and duplicate it or improve on it. He had the artist's wish to create something beautiful, and with it was the belief that he could provide well for his wife and children, and raise the potter's art to a new height if he could learn the secret of this enamel. That thought became his lodestone, and he left all his other work to accomplish it. Much as he knew about glass, he knew nothing about enamel. He had no notion of the materials he should need, nor how he was to combine them. He started to make earthen vessels without knowing how other men had made them. He knew that he should need a furnace, and so he built one, although he had never seen a furnace fired.

The attempt seemed foolhardy from the start. What

he had saved he spent in his attempts to find the right materials. Soon his savings were gone, and he had to look about for a new means of living. A survey and plan of the great salt-marshes of Saintonge was wanted in 1543, and Palissy obtained the work. He finished it, was paid the stipulated sum, and immediately spent it in fresh experiments to find the coveted enamel. But he could not find it. One experiment after another ended in rebuff. He labored day and night, and the result of all his labors was the same. But the desire to find that enamel had possessed Palissy's mind, and it was not a mind to veer or change.

The man was beset by friends who told him he was mad to continue the chase, and that his undoubted talents in other lines were being wasted. He was implored, reproached, and belabored by his wife, who begged him to leave his furnace, and turn to work that would feed and clothe his growing family. He might well have seemed a fanatic, he might well have seemed distraught and cruel to his family, but he met each protest with a simple frankness that disarmed all attacks and showed his indomitable purpose. Those were days of intense suffering for Palissy, and later he described them in his own writings in a way that showed his real depth of feeling and his constant struggle against what he held to be temptations.

He borrowed money to build a new furnace, and when this was done he lived by it, trying one combination of materials after another in his search for the secret of the enamel. Those were superstitious days, and some of his more ignorant neighbors thought

that Bernard Palissy must be in league with the devil, since he spent day and night feeding fuel to his furnace, and sending a great volume of smoke and sparks into the air. Some said he was an alchemist trying to turn base metals into gold, some that he was discovering new poisons, some frankly believed that his learning had turned his mind and made him mad. They were all certain of one thing, and that was that his great fires were providing very ill for his family, who became in time a charge on the town's charity.

For sixteen years Palissy experimented. For sixteen years he had to resist the reproaches of wife and children, and the threats of neighbors. That was an epic struggle, well worth the recording. We can picture the little mediæval town, surrounded by its salt marshes, the prosperous burghers, and the strange man, Bernard Palissy, at whom all others scoffed, whose children played in the streets in rags and tatters, but who, himself, was always working at his furnace with demoniac zeal. "Too much learning," says one burgher, shaking his head. "What business had a simple glass-worker to study those texts out of Italy?" "Seeking for more learning than other folk have is apt to league one with the Evil One," says number two. "Bernard has sold his soul. He will fall in his furnace some day, and go up in smoke." "Nay," says the third burgher, "he will live forever, to bring shame to our town of Saintes. He is like one of those plagues the priests tell us of." And he crosses himself devoutly.

Palissy, the Potter, after an Unsuccessful Experiment

But Palissy cared for nothing but to learn that secret. At first he had had a workman to help him; now he let him go. He had no money to pay him, and so gave him all his clothes except those he had on. He knew his family were starving, and he dared not go out into the streets for fear of the maledictions of his neighbors. But he fed that furnace and he melted his different compositions. When he could get no other fuel he turned to the scant furnishings of his house. He burned his bed and chairs, his table, and everything that was made of wood. He felt that he was now on the verge of his discovery; but he must have more fire. He tore strips of board from the walls, and piled them in the furnace. Still he needed more heat, and ran out into the yard behind his dwelling. There were sticks that supported vines, and a fence that ran between his land and the next. He took the wood of the fence, the sticks of the vines, and hurried back with them to the furnace. He threw them on the blaze, he bent over his composition, and he found the secret answered for him. After sixteen years he learned how to make that rare enamel.

It was a glorious achievement, and it brought Palissy fame and fortune. With his new knowledge he had soon fashioned pottery, decorated with rustic scenes, and exquisitely enameled, that all lovers of works of art desired at any price. The first pieces of his rustic pottery soon reached the court of France, and Henry II and his nobles ordered vases and figures from him to ornament the gardens of their châteaux. Catherine de' Medici became his patron, and the powerful Con-

stable de Montmorenci sent to Saintes for Palissy to decorate his château at Ecouen. Fragments of this work have been preserved, exquisite painted tiles, and also painted glass, setting forth the story of Psyche, which Palissy prepared for the château.

The people of Saintes now found that their madman, instead of bringing obloquy upon their town, was to bring it fame. The Reformation had made many Protestants in that part of France, and Palissy was one of them. But when the Parliament of Bordeaux, in 1562, ordered the execution of the edict of 1559, that had been directed against the Protestants, the Catholic Duke of Montpensier gave him a special safeguard, and ordered that his porcelain factory should be exempted from the general proscription. Party feeling ran very high, however, and in spite of the Duke's safeguard Palissy was arrested, his workshop ordered destroyed by the judges at Saintes, and the King himself had to send a special messenger to the town and claim that Palissy was his own servant, in order to save his life. The royal family, in spite of their many faults, were sincere lovers of beautiful workmanship, and they summoned Palissy to Paris, where they could insure his safety. Catherine de' Medici gave him a site for his workshop on a part of the ground where the Palace of the Tuilleries stood later, and used often to visit him and talk with him about his art. He made the finest pieces of his porcelain here in Paris. Here he also resumed his earlier studies, and came to lecture on natural history and physics to all the great scholars of the day. When the massacre of St. Bartholomew's

Eve deluged France with the blood of Protestants Catherine saw that Palissy was spared from the general destruction.

Palissy had shown the inborn courage of his nature during those sixteen lean years in Saintes. The perilous ups and downs of life in sixteenth century France were to show that courage in another light. In spite of royal favor the Catholic League reached for him, and in 1588, when he was nearly eighty years old, he was arrested by order of the Sixteen, thrown into the Bastille, and threatened with death. Henry III, son of Catherine, and in his own way a friend of artists, went to see Palissy in prison. "My good friend," said the King, "you have now been five and forty years in the service of my mother and myself; we have allowed you to retain your religion in the midst of fire and slaughter. Now I am so pressed by the Guises and my own people that I am constrained to deliver you up into the hands of your enemies, and to-morrow you will be burned unless you are converted."

"Sire," answered the old man, "I am ready to resign my life for the glory of God. You have told me several times that you pity me, and I, in my turn, pity you, who have used the words *I am constrained*. It was not spoken like a king, sire; and these are words which neither you nor those who constrain you, the Guisards and all your people, will ever be able to make me utter, for I know how to die."

The King, however, admiring Palissy's talents, and remembering his mother's fondness for the artist, would not give him up to the party of the League.

Instead he let him remain in his dungeon in the Bastille, where he died in 1589.

The maker of Palissy ware, as it is called, had many talents, and among them was that of the writer. During his days in prison he busied himself in penning his philosophic, religious, and artistic meditations, as many other illustrious prisoners have done. His autobiography is curious, and its note of sincerity has given it great value as a human document. Says Lamartine of the writings of Palissy, they are "real treasures of human wisdom, divine piety, and eminent genius, as well as of great simplicity, vigor, and copiousness of style. It is impossible, after reading them, not to consider the poor potter one of the greatest writers of the French language. Montaigne is not more free and flowing, Jean-Jacques Rousseau is scarcely more graphic; neither does Bossuet excel him in poetical power."

But Palissy did not explain his art of enamel in detail in any of his writings, and after the death of his brothers or nephews, who succeeded to his work, the secret of Palissy ware, like that of certain other arts of the Renaissance, was lost.

Palissy did not decorate his porcelain with flat painting. His figures, which usually dealt with historical, mythological, or allegorical subjects, were executed in relief, and colored. These colors were bright, and were generally yellows, blues, and grays, although sometimes he used greens, violets, and browns. He never acquired the pure white enamel of Luca della Robbia, nor that of the faience of Nevers. His enamel is hard,

but the glaze is not so fine as that of Delft. The back of his ware is never all the same color, but usually mottled with several colors, often yellow, blue, and brown.

Palissy's studies in natural history helped him when he came to decorate his pottery. The figures are strikingly true in form and color, and seem to have been moulded directly from nature, as they probably were. Thus the fossil shells which he frequently used in his border decorations are the shells found in the Paris basin, his fish are those of the Seine, his plants, usually the watercress, the hart's tongue, and the maidenhair fern, are those which he found in the country about Paris. His rustic scenes have that same charm of fidelity to nature.

He also made very beautiful tiles to overlay walls, stoves, and floors. The château at Ecouen has a large room entirely paved with them, and many are to be seen in the chapel. They bear heraldic designs, the devices of the Constable de Montmorenci, and the colors are fresh and bright, due to the artist's unique method of enameling.

Like so many Renaissance artists Palissy tried his skill in many lines. If his most remarkable work was his "rustic pieces," as they are called, great dishes ornamented with fishes, reptiles, frogs, shells, and plants in relief, intended to be used as ornaments and not for service, scarcely less interesting were his statuettes, his stands for fountains, his "rustic figures" for gardens, his candlesticks, ewers and basins, saltcellars, ink-stands, and baskets. Large collections of his

work are to be found in the Louvre, the Hôtel de Cluny, and at Sèvres. Many pieces have strayed into the hands of great private collectors of rare porcelain, and both England and Russia have many fine examples of his masterpieces.

He had two assistants, either brothers or nephews, and they knew the secret of his process. They had worked with him, and they continued his art into the reign of Henry IV. One of their productions shows that king surrounded by his family. But these successors had not the artistic instinct or touch of the master. They had little originality, and speedily became servile copyists, so that Palissy ware for a time lost the high place it had held. But these successors did not hand on the secret, and when no more of the ware was forthcoming good judges of the potter's art found it easy to distinguish between the work of Bernard and of his followers, and his own porcelain was again enthroned among the greatest productions of French art. Connoisseurs of to-day find it easy to know real Palissy ware.

Such is the story of a great artist of the Renaissance in France, of a man born with the love of beauty, who found a new way of giving the world delight, and who overcame what seemed almost superhuman trials.

III

GALILEO AND THE TELESCOPE
1564–1642

THREE days before the death of the great Italian Michael Angelo, in the year 1564, there was born in Pisa a boy who was given the name of Galileo Galilei, and who was destined to become one of the greatest philosophers and inventors the world has ever known. He came of a noble family of Florence, which had originally borne the name of Bonajuti, but had later changed it to that of Galilei, and he is usually known by his baptismal name of Galileo, according to the Italian custom of that age. His father was a merchant, engaged in business in Pisa, a man well versed in the Latin and Greek tongues, and well known for his knowledge of mathematics. He was anxious that each of his three sons should have a good education, and so he sent Galileo, his eldest boy, to the famous monastery of Vallombrosa, situated in a beautiful wooded valley not far from Florence. But the father did not intend his son to become a priest, and so, when he found his thoughts tending in that direction, he took him away from the monastery, planning to make him a merchant like himself.

But the mind of the young Galileo was already remarkably acute. He was a good musician, a skilful

draughtsman and painter, something of a poet, and had shown considerable talent in designing and building a variety of toy machines. His father soon decided that his son's bent did not lie in the direction of a dealer in cloths, and, casting about for a scientific career, chose that of medicine for Galileo. So he took up this study at the University of Pisa.

One afternoon the youth of eighteen went to the great Cathedral of the city. He knelt to make his devotions. From the roof of the nave hung a large bronze lamp, and as the boy watched he saw an attendant draw the lamp toward him to light it, and then let it swing back again. The swinging caught his attention, and he watched it with more and more interest. At first the arc of the swinging lamp was wide, but gradually it grew less and less. But what struck him as singular was that the oscillations all seemed to be made in the same time. He had no watch, so he put his fingers on his wrist in order to note the pulse-beats. As nearly as he could determine the swings of the lamp as they lessened were keeping the same times.

When he went home he began to experiment with this idea of the swinging lamp, or pendulum as it came to be called, and soon had constructed an instrument which marked with very fair accuracy the rate and variation of the pulse-beats. It was imperfect in many respects, but when he showed it to his teachers at the university they were delighted with it, and it was soon generally used by the physicians of the day under the name of the Pulsilogia.

But, to his father's dismay, the young Galileo did

not show great interest in the study of medicine. Instead he spent his time studying the mathematics of Euclid, and from them went on to the writings of Archimedes and the laws of mechanics. These latter absorbed him, and fresh from reading them he constructed for himself a hydrostatic balance, the purpose of which was to ascertain accurately the relative proportions of any two metals in an alloy. He wrote an essay on his invention, and circulated it among his friends and teachers. This added to his reputation as a scientist, but brought him no money. His family were poor, and he needed a means of support, and so he applied for, and after a time obtained, appointment to the post of Professor of Mathematics at the University of Pisa.

For centuries the laws of mechanics as laid down by the Greek Aristotle had been accepted without much dispute by the civilized world. But a spirit of new thought and investigation was now rising in Europe, and more especially in Italy. Galileo determined to study the laws of mechanics by experiment, and not, as so many earlier scientists had done, by argument or mere theoretical opinions. Therefore he undertook to establish definitely the laws relating to falling bodies.

Aristotle, almost two thousand years before, had announced that if two bodies of different weights were dropped from the same height the heavier would reach the ground sooner than the lighter, according to the proportion of their weights. Galileo doubted this, and decided to try it. Accordingly he assembled the teachers and students of the university one morning

about the base of the famous Leaning Tower of Pisa. He himself climbed to the top, carrying with him a ten-pound shot and a one-pound shot. He balanced them on the edge of the tower and let them fall together. They struck the ground together. As a result of this experiment Galileo declared three laws in relation to falling bodies. He said that if one neglected the resistance of the air, or in other words supposed the bodies to fall through a vacuum, it would be found, first, that all bodies fall from the same height in equal times; second, that in falling the final velocities are proportional to the times; and third, that the spaces fallen through are proportional to the squares of the times.

The first of these laws was shown by his experiment on the Leaning Tower. To show the others he built a straight inclined plane with a groove down its centre. A bronze ball was free to move in the groove with the least possible friction. By means of this he showed that no matter how much he inclined the plane, and so changed the time, the ball would always move down it according to the laws he had stated.

But in disproving the accuracy of the old laws of Aristotle the young scientist had raised a hornet's nest about his ears. The men of the old school would not believe him, a conspiracy was set on foot against him, and finally the criticism of his new teachings grew so severe that he was forced to resign his position, and move to Florence.

In spite of his wide-spread reputation no school or university was ready to welcome the young scientist.

He was known as a man of a very original turn of mind, and therefore one who would be apt to clash with those who clung to their belief in the old order of thought. At last, however, he succeeded in obtaining the chair of Professor of Mathematics at the University of Padua, then one of the greatest seats of learning in Italy. Here again he showed the great scope of his knowledge, and wrote on military architecture and fortifications, the laws of motion, of the sphere, and various branches of mechanics. He invented a machine for raising water, and was granted a patent which secured him his rights in it for twenty years, and he also produced what he called his Geometrical and Military Compass, but what was later commonly known as the Sector.

Galileo's fame as a teacher had now spread widely throughout Europe, and students began to flock to Padua to study under him. He had a large house, where a number of his private pupils lived with him, a garden, in which he delighted, and a workshop. Here he experimented on his next invention, that of the air thermometer. One of his friends, Castelli, wrote of this in a letter many years later, dated 1638. "I remember," he writes, "an experiment which our Signor Galileo had shown me more than thirty-five years ago. He took a small glass bottle about the size of a hen's egg, the neck of which was two palms long, and as narrow as a straw. Having well heated the bulb in his hand, he inserted its mouth in a vessel containing a little water, and, withdrawing the heat of his hand from the bulb, instantly the water rose in the neck

more than a palm above its level in the vessel. It is thus that he constructed an instrument for measuring the degrees of heat and cold."

In 1604 the attention of all the astronomers of Europe was attracted by a new star which suddenly appeared in the constellation Serpentarius. Galileo studied it, and shortly began to lecture on the comparatively new science of astronomy. Formerly he had taught the old system of Aristotle to his classes, now, after a searching investigation, he declared his belief in the contrary conclusions of Copernicus. This study led him on and on. He became interested in the magnetic needle, and its use as a compass in navigation. Columbus' discovery of its changing its position according to its relation to the North Pole took place on his first voyage to America, and reports of this had reached Padua. All educated men were rousing to the fact that the age was fertile with new discoveries in every branch of knowledge, and Galileo and those who were working with him gave eager heed to each month's batch of news.

Mere chance is said to have brought about the making of the first telescope. The story goes that an apprentice of Hans Lipperhey, an optician of Middleburg, in Holland, was, one day in October, 1608, playing with some spectacle lenses in his master's shop. He noticed that by holding two of the lenses in a certain position he obtained a large and inverted view of whatever he looked at. He told Master Hans about this, and the optician fixed two lenses in a tube, and looking at the weathercock on a neighboring steeple

Galileo's Telescope

saw that it seemed much nearer and to be upside down. He hung the tube in his shop as a curious toy, and one day the Marquis Spinola examined it and bought it to present to Prince Maurice of Nassau. Soon a number of Hans Lipperhey's scientific neighbors were trying to make copies of his tube, and before very long reports of it were carried to Italy. The news reached Galileo while on a visit to Venice in June, 1609. This is his account of what followed, taken from a letter written to his brother-in-law Landucci, and dated August 29, 1609.

"You must know then that about two months ago a report was spread here that in Flanders a spy-glass had been presented to Prince Maurice, so ingeniously constructed that it made the most distant objects appear quite near, so that a man could be seen quite plainly at a distance of two miles. This result seemed to me so extraordinary that it set me thinking, and as it appeared to me that it depended upon the laws of perspective, I reflected on the manner of constructing it, and was at length so entirely successful that I made a spy-glass which far surpasses the report of the Flanders one. As the news had reached Venice that I had made such an instrument, six days ago I was summoned before their Highnesses, the Signoria, and exhibited it to them, to the astonishment of the whole senate. Many of the nobles and senators, although of a great age, mounted more than once to the top of the highest church tower in Venice, in order to see sails and shipping that were so far off that it was two hours before they were seen, without my spy-glass, steering

full sail into the harbor; for the effect of my instrument is such that it makes an object fifty miles off appear as large as if it were only five.

"Perceiving of what great utility such an instrument would prove in naval and military operations, and seeing that His Serenity the Doge desired to possess it, I resolved on the 24th inst. to go to the palace and present it as a free gift." So Galileo did, and as a result the senate elected him to the Professorship at Padua for life, with a salary of one thousand florins yearly.

But what were Galileo's claims to the invention of this great instrument? Here is what he wrote in 1623. "Perhaps it may be said that no great credit is due for the making of an instrument, or the solution of a problem, when one is told beforehand that the instrument exists, or that the problem is solvable. It may be said that the certitude of the existence of such a glass aided me, and that without this knowledge I would never have succeeded. To this I reply, the help which the information gave me consisted in exciting my thoughts in a particular direction, and without that, it is possible they may never have been directed that way; but that such information made the act of invention easier to me I deny, and I say more—to find the solution of a definite problem requires a greater effort of genius than to resolve one not specified; for in the latter case hazard, chance, may play the greater part, while in the former all is the work of the reasoning and intelligent mind. Thus, we are certain that the Dutchman, the first inventor of the telescope, was a simple spectacle-maker, who, handling by chance different forms of

glasses, looked, also by chance, through two of them, one convex and the other concave, held at different distances from the eye; saw and noted the unexpected result; and thus found the instrument. On the other hand, I, on the simple information of the effect obtained, discovered the same instrument, not by chance, but by the way of pure reasoning. Here are the steps: the artifice of the instrument depends either on one glass or on several. It cannot depend on one, for that must be either convex, or concave, or plain. The last form neither augments nor diminishes visible objects; the concave diminishes them, the convex increases them, but both show them blurred and indistinct. Passing then to the combination of two glasses, and knowing that glasses with plain surfaces change nothing, I concluded that the effect could not be produced by combining a plain glass with a convex or a concave one; I was thus left with the two other kinds of glasses, and after a few experiments I saw how the effect sought could be produced. Such was the march of my discovery, in which I was not assisted in any way by the knowledge that the conclusion at which I aimed was a verity."

The telescope that Galileo presented to the Doge of Venice, and which was later lost, consisted of a tube of lead, with what is called a plano-concave eye-glass and a plano-convex object glass, and had a magnifying power of three diameters, which made objects look three times nearer than they actually were, and as a result nine times larger. The tube was about seventy centimeters long and about forty-five millimeters in di-

ameter. It was first used in public from the top of the campanile in the piazza at Venice on August 21, 1609, and the most distant object that could be seen through it was the campanile of the church of San Giustina in Padua, about thirty-five kilometers away.

As soon as Galileo returned to his home in Padua he busied himself with improving his invention. First he constructed a new telescope, which as he said "made objects appear more than sixty times larger." Soon he had a still better one, which enlarged four hundred times. He used this to examine the moon, and said that it brought that body "to a distance of less than three semi-diameters of the earth, thus making it appear about twenty times nearer and four hundred times larger than when seen by the unaided eye." To use the instrument more accurately he built a support which held it firmly. He had also now learned to make the lenses adjustable, by fixing the tubes that held them so that they could be drawn out of, or pushed into the main tube of the telescope. To see objects not very far distant very clearly he would push the glasses a little way apart, and to see things very far distant he drew the glasses together.

But this last telescope did not altogether satisfy him, and so he built a still larger one. This brought objects more than thirty times closer and showed them almost a thousand times larger in size. With this he discovered the moons of Jupiter, and some of the fixed stars, and added much to what was already known concerning the Milky Way, a region of the sky which had long been a puzzle to astronomers.

He spent a great part of his time now in his workshop, making and grinding glasses. They were expensive and very difficult to prepare properly. Out of more than one hundred that he ground at first he found only ten that would show him the newly found moons of Jupiter. The object glasses were the more difficult, for it was this glass which had to bring to a focus as accurately as possible all the rays of light that passed into the telescope.

As the voyage of Columbus had brought a new world in the western ocean to the notice of Europe, so Galileo's discoveries with his telescope brought forth a new world in the skies. Galileo wrote out statements of his discoveries, and sent these, with his new telescopes, to the princes and learned men of Italy, France, Flanders, and Germany. At all the courts and universities the telescopes were received with the greatest enthusiasm, and put to instant use in the hope of discovering new stars. But again the followers of Aristotle, those who were unwilling to admit that anything new could be learned about the laws of nature or the universe, arose in wrath. They attacked Galileo and his discoveries. They would not admit that Jupiter had four attendant moons, although these satellites could be seen by any one through the telescope, and a little later, when Galileo stated that the planet Saturn was composed of three stars which touched each other (later found to be one planet with two rings) they rose up to denounce him. But as yet these protests against the discoverer had little effect. Europe was too much interested in what he was show-

ing it to realize how deeply he might affect men's views of the universe.

Fame was now safely his. Men came from all parts of Europe to study under this wonderful professor of Padua. But teaching gave him too little time to carry on his own researches. So he looked about for some other position that would give him greater leisure, and finally stated his wishes to Cosimo II, Duke of Florence. Galileo had named the satellites of Jupiter after the house of Medici, to which this Duke belonged, and Cosimo was much flattered at the compliment. As a result he was soon after made First Mathematician of the University of Pisa, and also Philosopher and Mathematician to the Grand Duke's Court of Florence.

Settled at last at Florence his work as an astronomer steadily went forward. He discovered that the planet Venus had a varying crescent form, that there were small spots circling across the face of the sun, which he called sun-spots, and later that there were mountains on the moon. He also visited Rome, where he was received with the greatest good-will by Pope Paul V and his cardinals, and where he met the leading scientists of the capital.

But Galileo's course was no less flecked with light and shade than were the sun and moon he studied. The envy of rivals soon spread false reports about him, and the professors at Pisa refused to accept the results of his studies. Then one of the latter stirred the religious scruples of the Dowager Grand Duchess by telling her that Galileo's conclusion that the earth had a double

motion must be wrong, since it was opposed to the statements of the Bible. Galileo heard of this, and wrote a letter in reply, in which he said that in studying the laws of nature men must start with what they could prove by experiments instead of relying wholly on the Scriptures. This was enough to set the machinery of his enemies in motion. Galileo's teachings were pointed out as dangerous to the teachings of the Church, and the officers of the Inquisition began to consider how they might best deal with him. Certain of his writings were declared false and prohibited, and he was admonished that he must follow certain lines in his teachings. He went to Rome himself, and saw the Pope again, but found that his friends were fewer and his enemies growing more powerful.

The theory of Copernicus that the earth and planets are in constant motion was the very foundation of Galileo's scientific studies, and yet the order of the Church now forbade him to use this theory. He went back to Florence out of health and despondent. His old students were falling away from him through fear of the Pope's displeasure, and he was left much alone. But his thirst for knowledge would not let him rest. He took up his residence in the fine old Torre del Gallo, which looks down on Florence and the river Arno, and went on with his work. He wrote out the results of his discoveries, and made a microscope from a model he had seen. Soon he had greatly improved upon his model, and had an instrument, which, as he said, "magnifies things as much as 50,000 times, so that one sees a fly as large as a hen." He sent copies

to some friends, and shortly his microscopes were as much in demand as his telescopes had been.

In 1632 he published what he called "The Dialogues of Galileo Galilei." This divided the world of Italy into two camps, the one those who believed in Aristotle and the old learning, the other those who followed Copernicus, Galileo, and Kepler. The Jesuits took up the gage he had thrown down, and Galileo found the Church of Rome arrayed against him. The sale of his book was forbidden, a commission was appointed to bring charges against him, and he was ordered to go to Rome for trial. The commission reported that Galileo had disobeyed the Church's orders by maintaining that the earth moves and that the sun is stationary, that he had wrongly declared that the movements of the tides were due to the sun's stability and the motion of the earth, and that he had failed to give up his old beliefs in regard to the sun and the earth as he had been commanded.

Galileo, although he was ill, went to Rome, and was placed on trial before the Inquisition. After weeks of weary waiting and long examinations he was ordered to take a solemn oath, forswearing his belief in his own writings and rejecting the conclusion that the sun was stationary and that the earth moved. Rather than suffer the pains of the Inquisition he agreed, and made his solemn declaration. According to an old story, now discredited, as he rose from his knees after the ceremony he whispered to a friend "*Eppur si muove*" (It does move, nevertheless). Whether he said this or not there can be no doubt but that the great

astronomer knew the performance was a farce, and that the world did move in spite of all the Inquisition could declare.

The Inquisition did its work ruthlessly. Notices of the sentence prohibiting the reading of Galileo's book and ordering all copies of it to be surrendered, and copies of the declaration he had made denying his former teachings, were sent to all the courts of Europe and to many of the universities. In Padua the documents were read to teachers and students at the university where for so many years Galileo had been the greatest glory of learning, and in Florence the Inquisitor read the sentence publicly in the church of Santa Croce, notices having been sent to all who were known to be friends or followers of Galileo, ordering them to attend. Thus his humiliation was spread broadcast, and in addition he was ordered to be held at Rome as a prisoner.

After a time he was permitted to go on parole to the city of Siena, which was at least nearer his home outside Florence. There he stayed until the Grand Duke Cosimo, who had stood by him, persuaded the Church that Galileo's health required that he be allowed to join his friends. At last he reached his home, and again took up his studies. His eyesight was failing, and eventually he became entirely blind, but meanwhile his speculations covered the widest fields of science, he studied the laws of motion and equilibrium, the velocity of light, the problems of the vacuum, of the flight of projectiles, and the mathematical theory of the parabola. He

wrote another book, dealing with two new sciences, and was busy with designs for a pendulum clock at the time of his death in 1642. He was buried in the church of Santa Croce, the Pantheon of Florence, under the same roof with his great fellow countryman, Michael Angelo.

What is known as the modern refracting telescope is based upon a different combination of lenses than that used by Galileo. Kepler studied Galileo's instrument, and then designed one consisting of two convex lenses. The modern telescope follows Kepler's arrangement, but Galileo's adjustment is still suitable where only low magnifying powers are needed, and is used to-day in the ordinary field- and opera-glass.

Galileo knew nothing of what we call the reflecting telescope. He found that by using a convex-lens as an object-glass he could bring the rays of light from any distant object to a focus, and it did not apparently occur to him that he could achieve the same end by the use of a concave mirror. James Gregory, a Scotchman, designed the first reflector in 1663, and described it in a book, but he was too poor to construct it. Nine years later Sir Isaac Newton, having studied Gregory's plans, built the first reflecting telescope, which is now to be seen in the hall of the Royal Society in London. But invention has gone yet farther in perfecting these instruments with which to study the skies, and the great telescopes of modern times have in most instances discarded Newton's reflector for the refracting instrument. And these are built on a tremendous scale.

The Yerkes telescope at Williams Bay, Wisconsin, has a refractor of forty inches, and the one built for the Paris Exposition of 1900, one of fifty inches. In numerous other details they have changed, and yet each is chiefly indebted to that simple spy-glass of Galileo, by which he was able to show the nobles and senators of Venice full-rigged ships, which without it were barely distant specks on the horizon. Or, going still farther back, the men who make our present telescopes are following the trail that was first blazed on the day when the Dutch apprentice of Middleburg chanced to pick up two spectacle lenses and look through the two of them at once.

Galileo made many great discoveries and inventions; there was hardly a field of science that he did not enter and explore; but his greatest work was to open a new world to men's attention. It was this that brought him before the Inquisition and that branded him as a dangerous heretic, and it was this that placed him in the forefront of the world's discoverers. Men might say that the earth stood still, because it suited them best to believe so, but Galileo gave the world an instrument by which it could study the matter for itself, and the world has gone on using that instrument and that method ever since.

IV

WATT AND THE STEAM-ENGINE
1736–1819

IT was no pressing need that drove John Gutenberg to the invention of his printing press, nor was it necessity that led to Galileo's discovery of the telescope, but it was a very urgent demand that led to the building of a steam-engine by James Watt. England and Scotland found that men and women, even with the aid of horses, could not work the coal mines as they must be worked if the countries were to be kept supplied with fuel. The small mines were used up, the larger ones must be deepened, and in that event it would be too long and arduous a task for men and women to raise the coal in small baskets, or for horses to draw it out by the windlass. A machine must be constructed that would do the work more quickly, more easily, and more cheaply.

A Frenchman named Denys Papin had built the first steam-engine with a piston. He had seen certain experiments that showed him how much strength there was in compressed air. He had noticed that air pressure could lift several men off their feet. His problem therefore was how best to compress the air, or, as it appeared to him, how to secure a vacuum. His experiments proved that he could do this by the use of

steam. He took a simple cylinder and fitted a piston into it. Water was put in the cylinder under the piston, a fire was lighted beneath it, and as the water came to the boiling point the piston was forced upward by the steam. Then the fire was taken away, and as the steam in the cylinder condensed, the piston was forced down by the air pressure above. He fastened the upper end of the piston to a rope, which passed over two pulleys. If a weight were hung to the other end of the rope it would be raised as the piston was forced down. In that way the air pressure did the work of lifting the weight, and the necessary vacuum was obtained by forming steam and then condensing it in the cylinder. This was a very primitive device, requiring several minutes for the engine to make one stroke, but it was the beginning of the practical use of steam as a motive power.

Thomas Newcomen, an English blacksmith by trade, first put Papin's idea to use. Instead of the rope and pulleys Newcomen fastened a walking-beam to the end of the piston, and attached a pump-rod to the other end of the walking-beam. He used the steam in the cylinder only to balance the pressure of the air on the piston, and let the pump-rod descend by its own weight. As the steam condensed the piston fell, and the pump-rod rose again. By this means he could pump water from a mine, or lift coal. His first engine was able to lift fifty gallons of water fifty yards at each stroke, and could make twelve strokes a minute. At first he condensed his steam by throwing cold water on the outside of the cylinder, but one day he discovered

that the engine suddenly increased its speed, and he found that a hole had been worn in the cylinder, and that the water with which he had covered the top of the piston was entering through this hole. This condensed the steam more rapidly, and he adopted it as an improvement in his next engine. A little later a boy named Humphrey Potter, who had charge of turning the cocks that let the water and steam into the cylinder, found a way of tying strings to the cocks so that the engine would turn them itself, and so originated what came to be known as valve-gear.

Newcomen's engine was a great help to the coal mines of England and Scotland, but it was very expensive to run, a large engine consuming no less than twenty-eight pounds of coal per hour per horse-power. Then it happened that in 1764 a small Newcomen engine that belonged to the University of Glasgow was given to James Watt, an instrument-maker at the university, to be repaired. To do this properly he made a study of all that had been discovered in regard to engines, and then set about to construct one for himself.

There are many stories told of the boyhood of James Watt. He lived at Greenock on the River Clyde in Scotland, and was of a quiet, almost shy disposition, and delicate in health. He was fond of drawing and of studying mechanical problems, but rarely had much to say about his studies. The story goes that as he sat one evening at the tea-table with his aunt, Mrs. Muirhead, she said reprovingly to him, "James Watt, I never saw such an idle boy: take a book or employ yourself usefully; for the last hour you haven't spoken

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a word, but taken off the lid of that kettle and put it on again, holding a cup or a silver spoon over the steam, watching it rise from the spout, and catching the drops it falls into. Aren't you ashamed of spending your time in this way?" And history goes on to presume that as the boy watched the bubbling kettle he was studying the laws of steam and making ready to put them to good use some day.

He picked out the trade of a maker of mathematical instruments, and went to London to fit himself for it. He was apprenticed to a good master and made rapid progress, but the climate of London was bad for his health, and as soon as his term of instruction was finished he went back to Scotland. There he found it difficult to get employment, but at last he obtained permission to open a small shop in the grounds of the University of Glasgow, and to call himself "Mathematical-instrument-maker to the University."

When the Newcomen engine was given to Watt to repair he studied it closely, and soon reached an important conclusion. ~~A~~ great amount of heat was lost whenever the cold water was let into the cylinder to condense the steam, and this loss vastly increased the expense of running the engine, and cut down its power. He saw that to prevent this loss the cylinder must be kept as hot as the steam that entered it. This led him to study the nature of steam, and he had soon made some remarkable discoveries in regard to it. He found that water had a high capacity for storing up heat, without a corresponding effect on the thermometer. This hidden heat became known as latent heat.

It was of course a matter of common knowledge that heat could be obtained by the combustion of coal or wood. Watt found that heat lay also in water, to be drawn out and used in what is called steam. If you change the temperature of water you find that it exists in three different states, that of a liquid, or water, that of a solid, or ice, and that of a gas, or steam. If water were turned into steam, and two pounds of this steam passed into ten pounds of water at the freezing point the steam would become liquid, or water, again, at 212° of temperature, but at the same time the ten pounds of freezing water into which the steam had been passed would also have been raised to 212° by the process. This shows that the latent heat of the two pounds of steam was sufficient to convert the ten pounds of freezing water into boiling water. That is the latent heat which is set free to work when the steam coming in contact with the cold changes the vapor from its gaseous to a liquid state. The heat, however, is only latent, or in other words of no use, until the temperature of the water is raised to 212°, and the vapor rises.

Mr. Lauder, a pupil of Lord Kelvin, writing of Watt's "Discoveries of the Properties of Steam," describes his results in this way: "Suppose you take a flask, such as olive oil is often sold in, and fill it with cold water. Set it over a lighted lamp, put a thermometer in the water, and the temperature will be observed to rise steadily till it reaches 212°, where it remains, the water boils, and steam is produced freely. Now draw the thermometer out of the water, but leaving it still in the

steam. It remains steady at the same point—212°. Now it requires quite a long time and a large amount of heat to convert all the water into steam. As the steam goes off at the same temperature as the water, it is evident a quantity of heat has escaped in the steam, of which the thermometer gives us no account. This is latent heat.

"Now, if you blow the steam into cold water instead of allowing it to pass into the air, you will find that it heats the water six times more than what is due to its indicated temperature. To fix your idea: suppose you take 100 lbs. of water at 60°, and blow one pound of steam into it, making 101 lbs., its temperature will now be about 72°, a rise of 12°. Return to your 100 lbs. of water at 60° and add one pound of water at 212° the same temperature as the steam you added, and the temperature will only be raised about 2°. The one pound of steam heats six times more than the one pound of water, both being at the same temperature. This is the quantity of latent heat, which means simply hidden heat, in steam.

"Proceeding further with the experiment, if, instead of allowing the steam to blow into the water, you confine it until it gets to some pressure, then blow it into the water, it takes the same weight to raise the temperature to the same degree. This means that the total heat remains practically the same, no matter at what pressure.

"This is James Watt's discovery, and it led him to the use of high-pressure steam, used expansively."

Newcomen, in making his steam-engine, had simply

made additions to Papin's model. Watt had already done much more, for in trying to find how the engine might be made of greater service he had discovered at the outset the principle of the latent heat of steam. He knew that in Newcomen's engine four-fifths of all the steam used was lost in heating the cold cylinder, and that only one-fifth was actually used in moving the piston. It was easy to see how this loss occurred. The cylinder was cooled at the top because it was open to the air, and was cooled at the bottom in condensing the steam that had driven the piston up so as to create a vacuum which would lower the piston for another stroke. Watt knew that what he wanted was a plan by which the cylinder could always be kept as hot as the steam that went into it. How was he to obtain this? He solved it by the invention of the "separate condenser." This is how he tells of his discovery. "I had gone to take a walk on a fine Sabbath afternoon, early in 1765. I had entered the green by the gate at the foot of Charlotte Street and had passed the old washing-house, when the idea came into my mind that as steam was an elastic body it would rush into a vacuum, and if a communication were made between the cylinder and an exhausted vessel it would rush into it, and might be there condensed without cooling the cylinder. I then saw that I must get rid of the condensed steam and injection-water if I used a jet as in Newcomen's engine. Two ways of doing this occurred to me. First, the water might be run off by a descending pipe, if an offlet could be got at the depth of thirty-five or thirty-six feet, and any air might be extracted

by a small pump. The second was to make the pump large enough to extract both water and air. . . . I had not walked farther than the golf-house when the whole thing was arranged in my mind."

This was the discovery that gave us practically the modern steam-engine, with its countless uses in unnumbered fields. Newcomen's engine was limited to the pressure of the atmosphere, Watt's could use the tremendous force of steam under higher and higher pressure. He led the steam out of the cylinder and condensed it in a separate vessel, thereby leaving the cylinder hot. He closed the cylinder top, and prevented the loss of steam. The invention may seem simple enough as we study it, but as a matter of fact it was the attainment of this result of keeping the cylinder as hot as the steam that enters it that has given us our steam-engine.

The morning following that Sunday afternoon on which the idea of the condenser had occurred to Watt he borrowed a brass syringe from a college friend, and using this as a cylinder and a tin can as a condenser tried his experiment. The scheme worked, albeit in a primitive way, and Watt saw that he was on the track of an engine that would revolutionize the labor of men. But he saw also that it would take both time and money to bring his invention to its most efficient form.

His instrument-making business had prospered, he had taken in a partner, and the firm now employed sixteen workmen. About the same time he married, and rented a house outside the university grounds. Soon

he was busily at work building a working model of his steam-engine.

A working model was very hard to make. Watt himself was a skilful mechanician, but the men who helped him were not. The making of the cylinder and the piston gave him the chief trouble. The cylinder would leak. It took him months to devise the tools that would enable him to make a perfect-fitting cylinder, and when he had accomplished that he still found that in one way or another a certain amount of steam would escape. Yet, although imperfect, his model was already many times more powerful than the Newcomen engine he had started with.

But before very long Watt found that this work was leading him into debt. He told his good friend Professor Black, who had discovered the latent heat of steam before Watt had, that he needed a partner to help him in his business of building engines. Black suggested Dr. Roebuck, who had opened the well-known Carron Iron Works near Glasgow. The two men met, and, after some negotiations, formed a partnership. Roebuck agreed to pay Watt's debts to the sum of a thousand pounds, to provide the money for further experiments, and to obtain a patent for the steam-engine. In return for this he was to become the owner of a two-third interest in the invention.

It was more difficult to secure a patent in those days than in later times, for both the courts and the public considered that the right to make use of any new invention should belong to the whole world, and not alone to one man or to a few men. Watt's models had to be

very carefully made, and his designs very accurately drawn if he was to secure any real protection, and the preparation of these took a vast amount of time. But Roebuck continued to encourage him, and on January 5, 1769, he was granted his first patent, the very same day on which another great English inventor, Arkwright, obtained a patent for his spinning-frame. This first patent covered Watt's invention of the condenser, but not his next invention, which was the double-acting engine, or in other words, a method by which the steam should do work on the downward as well as on the upward stroke.

With his patent secured Watt spent six months building a huge new engine, which he had ready for use in September, 1769. In spite of all his painstaking it was only a partial success. The cylinder had been badly cast, the pipe-condenser did not work properly, and there was still the old leakage of steam at the piston. Men began to doubt whether the new engine could ever be made to accomplish what Watt claimed for it, but although he realized the difficulties the inventor would not allow himself to doubt. Unfortunately his way was no longer clear. Dr. Roebuck met with reverses and had to end the partnership agreement, and Watt had to borrow money from his old friend Professor Black to secure his patent. To add to his distress his wife, who had been his best counselor, died.

Dr. Roebuck had owed money to a celebrated merchant of Birmingham named Matthew Boulton. Boulton had heard a great deal about Watt's engine, and now consented to take Roebuck's interest in Watt's in-

vention in payment of the debt. At the same time the firm of Boulton and Watt was formed, and in May, 1774, Watt shipped his trial engine south, and set out himself for Birmingham.

Boulton was a business genius, and Watt now found that he could leave financial matters entirely to his care, and busy himself solely with his engine. He had better workmen, better appliances, and better material in Birmingham than he had had in Glasgow, and the engine was soon beginning to justify his hopes. But the original patent had only been granted for fourteen years, and six of these had already passed. Boulton was not willing to put money into the building of a great factory until he was sure that the engines would be secured to the firm. Therefore more time had to be spent in obtaining an extension of the patent. This was finally done, and Watt was granted a term of twenty-four years. At once Boulton set to work, the first engine factory rose, and hundreds of men in England turned to Birmingham to see how much truth there was in the wonderful stories that had been spread abroad of the new invention.

Men soon learned that the stories were true. Orders began to flow in, and Watt had his hands full in traveling about the country superintending the erection of his steam-engines. The mines of Cornwall had become unworkable, and as a great deal depended on the success of the engine in such work, he traveled to Cornwall to make sure that there should be no faults. The miners, the engineers, and the owners had gathered to see the new engine. It stood the test splendidly,

making eleven eight-foot strokes per minute, which broke the record. After that the other mines of Great Britain discarded the old expensive Newcomen engine, and sent in orders for Watt's. The firm prospered, and the inventor began to feel some of the material comforts of success. He had married a second time, and made a home for his wife and children in Birmingham. Now, when he could spare the time from superintending the workmen and traveling over the country, he gave his thoughts to further inventive schemes.

Watt had not only invented the condenser and the double-acting engine, he had produced an indicator for measuring the pressure of steam in the cylinder, and also what was called the fly-ball governor, which took the place of the throttle-valve he had first used to regulate the speed of his engines. These improvements had so increased the uses of the engine that scores of rival inventors were abroad, and therefore he decided to secure a second patent. This he did in 1781, the patent being issued "for certain new methods of producing a continued rotative motion around an axis or centre, and thereby to give motion to the wheels of mills or other machines." The next year he secured still another patent, and now he had so perfected his double-acting engine that it had a regular and easily controlled motion, in consequence of which, as he said in his specifications, "in most of our great manufactories these engines now supply the place of water, wind and horse mills, and instead of carrying the work to the power, the prime agent is placed wherever it is most convenient to the manufacturer." This meant that the steam-

engine had now reached the point where it could be made to serve for almost any purpose and placed in almost any position that might be required.

There was one further step for Watt to take in the development of his invention. He wished a more powerful engine than his double-acting one, and so he produced the "compound" engine. This was really two engines, the cylinders and condensers of which were so connected that the steam which had been used to press on the piston of the first could then be used to act expansively upon the piston of the second, and in this way the second engine be made to work either alternately or simultaneously with the first. And this compound engine is practically the very engine that we have to-day. Improvements have been made, but they have been made in details. The piston-rings invented by Cartwright have prevented the escape of steam, and so permitted the use of a higher pressure than Watt could achieve, and the cross-head invented by Haswell has provided the piston with a better bed on which to rest and freed it from a certain friction.

The firm of Boulton and Watt had a successful career, and in time the sons of the two partners took the latters' places. Watt had occasion to protect his patents by a suit at law, but he was victorious in this, and by the time the patent rights had expired the firm had built up such a large business that it was safe from rivals. Confident of his son's ability to carry on the business Watt at length retired, to busy himself in studying other inventions, to cultivate his garden, and to revisit familiar scenes in his beloved Scotland.

The steam-engine had come to take its place in the great onward march of progress. Men were already at work planning to make it move cars across the land and ships upon the sea. It was to revolutionize the manufacture of almost everything; what men and women had done before by hand it was now to do, and, devised at first because of the great need of a new way to work the coal mines, it was to provide a motive power to accomplish all kinds of labor.

Such is the story of how James Watt took Newcomen's simple piston and cylinder and so harnessed steam that he could make it do the work he wanted.

V

ARKWRIGHT AND THE SPINNING-JENNY

1732–1792

ALL the great English inventors have sprung from families of small means, and have had to work for their living. Richard Arkwright, born at Preston, in Lancashire, December 23, 1732, was no exception to this rule. He was the youngest of thirteen children, and his parents were as poor as the proverbial church mice. He had no real education, only such as he could pick up by chance, but he made the most of such chances as came his way. He was apprenticed to a barber at Bolton, and later took up that business for himself. It was an occupation in which he would be apt to glean much gossip and many stray scraps of information, but little that would tend to broaden his mind. Perhaps he realized this for himself, and concluded that the hair-dressing line was not to be his destiny, for when he was in the neighborhood of twenty-eight years of age he retired from his barber-shop, and became a traveling dealer in hair and dyes. This would at least allow him to see something more of the world.

His prospects at this new trade were good. He had come upon a new method of dyeing hair and preparing it to be made into wigs. Wigs were the fashion, and Arkwright had an excellent process, and was an ener-

getic and resourceful dealer. He saw something of the country world of England, the men and women in it, what they wanted, and what they needed. Doubtless his inventive mind was already revolving improvements for them. The dealer in dyes and wigs was a shrewd and canny man. Carlyle had this to say concerning him and his progress : "Nevertheless, in stropping of razors, in shaving of dirty beards, and the contradictions and confusions attendant thereon, the man had notions in that rough head of his! Spindles, shuttles, wheels, and contrivances, plying ideally within the same; rather hopeless-looking, which, however, he did at last bring to bear. Not without difficulty."

There is always a strain of romance, or at least adventure, in the life of the itinerant pedlar, something of the free-footedness of the gypsy, and something of the acumen of those Eastern traders who traveled in caravans from the Orient. But doubtless we see the charm more clearly than the traveler himself. It may have been, and most likely was, a workaday job for Richard Arkwright. But consider the romance that underlay it! This country vendor of hair was to become one of the world's great inventors, and to kneel before his sovereign for the accolade that was to make him knight. Figaro of Seville, famed as he was, was none superior to the Lancashire barber.

He traveled much through South Lancashire and Cheshire, and there he came in daily contact with the cotton-spinners. A weaver of great ingenuity and tireless purpose, James Hargreaves, had invented what was known as a spinning-jenny, an arrangement by which

many spindles, fastened in a wooden frame, would work together by the turning of a fly-wheel. This machine could do the work of many spinners, and in a much shorter time. The rovings of cotton went under a bar-clasp that took the place of the spinner's finger and thumb. This bar-clasp could be moved backward and forward on a rod as the spinner's hand would do when stretching the thread and winding it on. It had a precision of action that resulted in a much greater regularity in the spun thread than by the earlier process. It was a very ingenious device, and Hargreaves deserved the greatest credit for the skill with which he solved the problem

But the spinners did not take kindly to this improvement. When they discovered that Hargreaves could do more spinning with less work with his machine, and could supply his own loom with all the woof that was needed instead of keeping three or four spinners employed, they grew highly indignant. They did not realize that the demand for cotton cloth was far greater than the supply, and that they could all be profitably employed operating the spinning-jenny. That panic which has so often come over people when they learn of a new device entering their field of action struck the cotton-spinners, and Hargreaves was regarded as a foe rather than a friend. Hargreaves was driven from Lancashire to Nottingham, and many of his larger jennies were broken by mobs. A few of the smaller machines were saved, but the people's mind was very evident.

Hargreaves' improvement on the old-fashioned

spinning-wheel dates from 1767, though he himself, it is said, had first used such a machine in 1764. Two men, Wyatt and Paul, of Birmingham, had earlier built a machine to spin stronger yarn than that usually used, but their machine had shown many defects, and they had abandoned its use. Arkwright knew of Hargreaves' jenny, but not of the other machine, and as he came upon none in use in his travels he cannot be held to have been under any obligations to this earlier device.

The manufacture of cotton goods was in a primitive state in England. Pure cotton fabrics could not be made, and the fustians that were produced had a warp of linen yarn in them, due to the fact that no way was known by which cotton yarn of sufficient strength could be spun. Arkwright soon learned these difficulties that arose from the absence of cotton warp and the deficiency of cotton weft, and his alert mind commenced to wonder whether he could not so improve on Hargreaves' jenny as to overcome these difficulties. He was not a skilled mechanic himself, and so, when he decided to take up the subject, he employed a clock-maker, named Kay, to help him. Realizing the hostility to any improvement on the part of the cotton-spinners, he gave out that he was engaged in building a machine to solve the world-old problem of perpetual motion.

Under this cloak he worked, and soon found that his new occupation was vastly more interesting than that of dealer in wigs had been. He was a shrewd man, and therefore, when he withdrew from that trade in 1767, it

is probable that he foresaw that he was on the track of something better. His idea was that cotton could be spun by rollers, and he said that this thought occurred to him as he happened to watch a red-hot iron bar lengthened out by passing between two rollers. But the iron would necessarily have to be drawn out in such a process, while the cotton wool could be indefinitely packed together. It would have to be taken hold of, and forcibly stretched as it passed through the pair of rollers, if it were to be drawn out, and not merely compressed. His solution of this problem was a machine that had two pairs of rollers, which were called drawing-rollers, the first pair of which revolved slowly in contact with each other, while the second pair revolved more rapidly in a similar way. One roller of each pair was covered with leather, and the other was fluted lengthwise. The two were pressed together by means of weights. In this manner the adhesion of the cotton wool was safely secured, and there was no chance of the rollers slipping around without drawing it in. The cotton passed through the two pairs of rollers, and its extension depended entirely on the difference in the velocity of the revolutions of the two pairs. When the proper fineness had been obtained in this way, the cotton, as it passed from the second pair of rollers, was twisted into a firm strong thread by spindles attached to the frame.

Arkwright realized that he must have assistance in order to put his machines on the market. He applied to a Mr. Atherton, and the latter, although he considered the venture a hazardous one, sent him two work-

Sir Richard Arkwright

men to help in building his first machine. When this was finished Arkwright went with it to Preston, and there set up his spinning-frame and began to use it in a room of the house that belonged to the Free Grammar School. His experiments convinced him of its success. Then he thought how he could best introduce his machine with least risk of rousing the popular fury. John Smalley, a liquor merchant and painter, had helped him build his machine, and after consultation, the two men decided to take the spinning-jenny to Nottingham, which lay in the heart of the frame-work stocking trade.

Arkwright's great opportunity lay in the fact that the manufacture of cotton hosiery had hitherto had to be carried on on a limited scale, owing to the difficulty of obtaining yarn that was sufficiently strong for the stocking-frames that were then used. At first he and John Smalley were associated with the Messrs. Wright, Nottingham bankers, but these bankers, figuring on the experience that had befallen the inventors of other spinning machines, soon withdrew their aid. But Arkwright was more fortunate in his next step. Samuel Need, a Nottingham manufacturer of stockings, and his partner, Jedediah Strutt, of Derby, who had himself invented a device for making ribbed stockings, became interested in his machine, tested it carefully, and with the experience they had already gained as practical manufacturers, decided in its favor. It was their approval that started Arkwright on the road to fortune.

Arkwright took out his first patent in 1769, the same year that Watt patented his steam-engine with a

separate condenser. A little later, with his partners Need and Strutt, he built a very complete factory at Cromford, on the Derwent River. He had already shown his power of originating and perfecting a working machine, now he showed an additional ability for organizing a great manufactory, and improving and adding new devices to his original model. This was the test of his strength, and perhaps the most wonderful part of his character. Many men have come upon new ideas, and many have sent them forth to improve the world's work, but only a few have developed them, day in and day out, until they stand forth as a finished achievement. That is the gauge, the test that has proved the inventor. Not Watt's first innovations on the stationary steam-engine, nor Stephenson's building of his original locomotive, nor Arkwright's discovery that rollers could be used to draw the cotton, but the years of trial and improvement Watt spent at Birmingham, and Stephenson in his shops at Killingworth, and Arkwright in his factory at Cromford, have made the three men famous in history. They were the years of patience and perseverance, which must come in the life of every great inventor to test his strength.

The country people about Cromford came to see Arkwright's machines, and wonder at them, and sometimes to buy a dozen pairs of stockings that had been made of Arkwright's yarn. But the big Manchester manufacturers refused to trade with him. The fine water-twist that was being spun on his spinning-frames was perfectly adapted to be used as warp, and would have supplied the demand for genuine cotton goods,

which otherwise had to be imported from India. But, though they needed his yarn, the manufacturers would not buy it from him, and he was forced to find some way of using his large output himself. First he used it to manufacture stockings, and then, in 1773, to make, for the first time in England, fabrics entirely of cotton. This was the turning point in England's trade in cotton goods. Heretofore she had not been able to meet the demands of her own people, now she was to commence a campaign that was ultimately to send her cloth to the farthest ends of the earth.

His powers of resistance were to be still further tested. An act was passed, based on the assumption that the English spinners could never compete with the fine Indian handiwork, that a duty of sixpence a yard should be levied on all calicoes, which were a variety of cotton goods originally imported from Calicut, in India. In addition, the sale of printed calicoes was forbidden. The customs officers immediately began to levy the duty on the products of Arkwright's mills, claiming that the goods were in reality calicoes, although they were made in England. It followed that merchants who had ordered goods from the Cromford Mill cancelled their orders, rather than pay the duty, and again Arkwright found his cottons piling up on his hands.

The act was too unfair to stand, and after a time was repealed. Cotton and all mixed fabrics were taxed threepence per yard, and the prohibition on printed cotton goods was withdrawn. The opposition of rival manufacturers could not in the nature of things long re-

tard what was to become one of the nation's main industries.

He took out his second patent in 1775, and it embraced almost the entire field of cloth manufacture. It contained innumerable devices that he had worked out during the years he had been experimenting at his factory. It covered "carding, drawing, and roving machines for use in preparing silk, cotton, flax, and wool for spinning." The man who had been a vendor of wigs had now revolutionized the whole spinning world. He had taught men and women to work at his machines, instead of in the old way of individual hand labor, he had organized a great business, and was showing the world that more could be accomplished by the division of labor and its control by one mind than could ever have resulted from individual initiative. In this way he was taking a most vital part in the progress of those new economic ideas that were dawning into consciousness toward the close of the eighteenth century.

It is so easy to see the successful result, so difficult to appreciate the trials that have been undergone. We look at the great picture and we admire the genius of the artist, but how rarely we realize the no less wonderful patience, the no less wonderful struggle that underlies what we see. The creator has not wrought easily, that is certain; and his greatness consists in what he has overcome.

Arkwright was ill with asthma during many of the years when he was fighting for his fortune, and time and again it seemed as if his strength must fail before

the task he had undertaken. But he was a great fighter, and so he won through. His workmen were offered bribes to leave his service, and teach his methods to rivals, his patents were infringed, right and left there was warfare, and he was fighting a score of enemies single-handed.

In 1781 he had to bring suit against Colonel Mordaunt, and eight other manufacturers, for infringing his patent. The influence of all the Lancashire cotton-spinners was aligned against his claims. They could not deny the fact that he had invented the spinning-jenny, but they said that the specifications of his patent were not sufficiently clear. The court upheld this contention, and declared the patent invalid. Arkwright withdrew the other suits he had started, and wrote and published his "Case," in order to set forth to the world the truth of his claims.

In 1785 he brought his case again into court, and this time Lord Loughborough ruled that his patent was valid. On account of this conflict of decisions the matter was referred to the Court of King's Bench. Here a Lancashire man named Highs, who had constructed a double jenny to work fifty-six spindles in 1770, was declared by Arkwright's opponents to be the real inventor. It was said that Arkwright had stolen this man's ideas. On such evidence Arkwright's claims were denied, and his patent overruled. This was the species of constant warfare with which he had to occupy himself.

Manchester had fought against the spinning-frame for years, but it was to receive the chief fruits of its

success. Arkwright built a mill there in 1780, and it prospered exceedingly, in spite of the fact that he no longer had the protection of his patents. He was such a good business man, such a splendid organizer, that he could overcome his enemies without that help, and in time he built up a fortune.

When he had started his first mill at Nottingham Arkwright had been obliged to use horse-power, and it was owing to the expense of such a system that he had soon moved to Cromford, where he could obtain water-power from the Derwent River. It was this that gave his yarn the name of water-twist. But in his Manchester Mill he made use of a hydraulic wheel, supplied with water by a single-stroke atmospheric steam-engine. Later Boulton and Watt's engines were installed, and with the most profitable results. As a result of these improvements the imports of cotton wool, which had averaged less than 5,000,000 pounds a year in the five years from 1771 to 1775, rose to an average of more than 25,000,000 pounds in the five years ending with 1790. England began to export cotton goods in 1781, which was sufficient evidence that the manufacture of such goods was proceeding more rapidly than the home demand for them. This was due largely to Arkwright's invention, to his building up of factories on new methods, and to the great help furnished to all machinery by the steam-engines of James Watt.

This is the romance of the dealer in wigs and dyes. He had won fame and fortune, and a powerful position in his country. In 1786 he was appointed High

Sheriff in Derbyshire, and the same year was knighted by George III. He died at Cromford in 1792.

His personality was strong, aggressive, dominating. Nothing could turn him from his course when he had made up his mind in regard to it. He was determined to make a fortune out of cotton-spinning, and he did, in spite of the loss of his patents, and the rivals who were always pursuing him. He stands high as inventor, and quite as high as one of the makers of modern commercial England.

VI

WHITNEY AND THE COTTON-GIN
1765–1825

COTTON-GROWING has been for a long time the main industry of the Southern United States, and the exporting of cotton by that part of the country has largely fed the mills of the world. Yet in 1784 the customs officers at Liverpool seized eight bags of cotton arriving on an American vessel, claiming that so much of the raw material could not have been produced in the thirteen states. In 1793 the total export of cotton from the United States was less than ten thousand bales, but by 1860 the export was four million bales. The chief reason for this marvelous advance was the cotton-gin, for which Eli Whitney applied for a patent in 1793.

Wherever cotton grew in the South there the cotton-gin was to be found. It brought prosperity and ease and comfort, it allowed the small as well as the large owner to have his share of the profits of the markets of the world. It gave the cotton country its living, and yet Whitney struggled for years to win the slightest recognition of his claims. He wrote to Robert Fulton, "In one instance I had great difficulty in proving that the machine had been used in Georgia, although at the same moment there were

three separate sets of this machinery in motion within fifty yards of the building in which the court sat, and all so near that the rattling of the wheels was distinctly heard on the steps of the court-house."

He came to the South from New England, having been born in Westborough, Worcester County, Massachusetts, December 8, 1765, educated at Yale College, and going to Georgia as teacher in a private family. General Greene, of Savannah, took a great interest in him, and taught him law. Whitney had been a good student, had an attractive personality, and had already shown a natural knack for mechanics. While he was teaching at the Greenes' home he noticed that the embroidery frame that Mrs. Greene used tore the fine threads of her work. He asked her to let him study it, and shortly had made a frame on an entirely different plan that would do the same work without injuring the threads. His hostess was delighted with it, and spread the word of her young teacher's ingenuity through the neighborhood.

As in all Southern mansions hospitality was rife at the Greenes', and it happened that one evening a number of gentlemen were gathered there who had fought under the General in the Revolution. The subject of the growing of cotton came under discussion, and some one spoke of the unfortunate fact that no method had been found for cleaning the cotton staple of the green seed. If that could be done cotton could be grown with profit on all the land that was unsuited for rice. To separate a single pound of the clean staple from the green seed took a whole day's work

for a woman. There was little profit in trying to grow much cotton at such a rate, and most of the cotton picking was done by the negroes in the evenings, when the harder labor of the fields was finished. Then Mrs. Greene pointed to Eli Whitney with a smile. "There, gentlemen," said she, "apply to my friend Mr. Whitney for your device. He can make anything." The guests looked at the young man, but he hastened to disclaim any such abilities, and said that he had never even seen cotton-seed.

But in spite of his disclaimer he began to consider whether he could make a machine that would help to separate the seed from the cotton. He went to see a neighbor, Phineas Miller, and talked over his plans with him. Miller became interested, and gave him a room in his house where he might carry on his experiments. He had to use very primitive implements, making his own tools and drawing his own wire. He worked quietly, only Mr. Miller and Mrs. Greene knowing what he was doing.

Whitney worked on his machine all the winter of 1793, and by spring it was far enough completed to assure him of success. Mr. Miller, who was a lawyer with a taste for mechanics, and who was, again like Eli Whitney, a New Englander and graduate of Yale, married Mrs. Greene after the General's death. It was he who actually made Whitney's machine a business possibility by proposing that he should become a partner with the inventor, and bear all the expenses of manufacturing it until they should secure their patent. They drew up a legal agreement to this effect, dated

May 27, 1793, and stipulating that all the profits should be equally divided between them.

There followed very soon the first dramatic scenes in the long battle between the owners of the cotton-gin and the public. The Southern people knew how invaluable such an invention would be to them; it meant food and shelter and better living all along the line; it would increase the value of their property a hundred-fold. So as soon as it became bruited abroad that Eli Whitney had such a machine in his workroom that spot became the Mecca for the countryside. Crowds came to beg for a look at the wonderful machine, and hung about the house and plotted to get in. But Whitney and Miller were afraid to let people see the invention until they had made sure of their patents on it, and so they refused to let the crowds have a look at it. Then the more reckless of the crowds threw all sense of fairness to the winds, and broke into Mr. Miller's house, seized the machine, and carried it off with them. Soon it was publicly displayed, and before Whitney could finish his model for the Patent Office a dozen machines, similar to his, were in use in the cotton fields.

Whitney's cotton-gin was made of two cylinders of different diameters, mounted in a strong wooden frame. One cylinder had a number of small circular saws that were fitted into grooves cut into the cylinder. The other cylinder was covered with brushes, and so placed that the tips of the bristles of these brushes touched the saw-teeth. The raw cotton was put in a hopper, where it was met by the teeth of the saws, and torn from the

seeds. The brushes then swept the cotton clear of the gin. The seeds were too large to go between the bars through which the series of saws protruded, and were kept apart by themselves. Of course many improvements were made upon this machine, but it was found that even in this original form it would enable one man, using two horse-power, to clean the seed from five thousand pounds of cotton in a day. That meant that fortunes could be made in the hitherto disregarded cotton fields of the South.

Whitney now went to Connecticut to finish certain improvements on the machine, to secure his patents, and to begin the manufacturing of as many gins as his partner Miller should find were needed in Georgia. The partners wrote frequently to each other, and their letters show the fierceness of the struggle they were waging to protect their rights. "It will be necessary," wrote Miller, "to have a considerable number of gins in readiness to send out as soon as the patent is obtained in order to satisfy the absolute demands and make people's heads easy on the subject; for I am informed of two other claimants for the honor of the invention of the cotton-gin in addition to those we knew before."

The two men did everything in their power to hasten the building of their gins. They knew their rivals were unscrupulous, and were in fact already trying their best to prejudice the minds of the more conservative Georgia cotton-growers against them. But money was very scarce, and the manufacture of the machines proved so costly that Whitney found it impossible to furnish as many gins as his partner wanted.

Whitney applied for his patent in 1793. The following April he went back to Georgia, where he found unusually large crops of cotton had been planted, in expectation of using the gin. As there were not enough of his gins ready rivals were pushing their inferior machines. One of these, called the roller-gin, destroyed the seeds by crushing them between two revolving cylinders, instead of separating them by teeth. A large part of the crushed seed was, however, apt to stay in the cotton after it had passed through the machine, and this form of gin did not therefore produce as satisfactory results as did Whitney's. Another rival was the saw-gin, which was almost identical with Whitney's gin, except that the saw-teeth were cut in circular rings of iron instead of being made of wire. This machine infringed the partners' patents, and caused them an almost endless series of expensive lawsuits.

Two years of conflict in the South proved the superiority of Whitney's invention over all other machines, but resulted in little actual profit. In March, 1795, he went north to New York, where he was kept for several weeks by illness. When he got back to his factory in New Haven he found that fire had wiped out his workshop, together with all his gins and papers. He was $4,000 in debt, and virtually bankrupt. Yet he had great courage, and fortunately his partner Miller had the same faith. When Whitney sent him the news from New Haven, Miller replied, "I think we ought to meet such events with equanimity. We have been pursuing a valuable object by honorable means, and I trust that all our measures have been such as reason and virtue

must justify. It has pleased Providence to postpone the attainment of this object. In the midst of the reflections which your story has suggested, and with feelings keenly awake to the heavy, the extensive injury we have sustained, I feel a secret joy and satisfaction that you possess a mind in this respect similar to my own—that you are not disheartened, that you do not relinquish the pursuit, and that you will persevere, and endeavor, at all events, to attain the main object. This is exactly consonant to my own determinations. I will devote all my time, all my thoughts, all my exertions, and all the money I can earn or borrow to encompass and complete the business we have undertaken ; and if fortune should, by any future disaster, deny us the boon we ask, we will at least deserve it. It shall never be said that we have lost an object which a little perseverance could have attained. I think, indeed, it will be very extraordinary if two young men in the prime of life, with some share of ingenuity, and with a little knowledge of the world, a great deal of industry, and a considerable command of property, should not be able to sustain such a stroke of misfortune as this, heavy as it is."

Whitney attempted to rebuild his factory, but the affairs of the firm were in extreme jeopardy. He had to pay twelve per cent. a year to borrow money for his work. Then certain English manufacturers reported that the cotton that was cleaned by Whitney's gin was not of good quality. The struggle was a hard one. He wrote to Miller, "The extreme embarrassments which have been for a long time accumulating upon me are now become so great that it will be impossible

for me to struggle against them many days longer. It has required my utmost exertions to exist without making the least progress in our business. I have labored hard against the strong current of disappointment which has been threatening to carry us down the cataract, but I have labored with a shattered oar and struggled in vain, unless some speedy relief is obtained. . . . Life is but short at best, and six or seven years out of the midst of it is to him who makes it an immense sacrifice. My most unremitted attention has been devoted to our business. I have sacrificed to it other objects from which, before this time, I might certainly have gained $20,000 or $30,000. My whole prospects have been embarked in it, with the expectation that I should before this time have realized something from it."

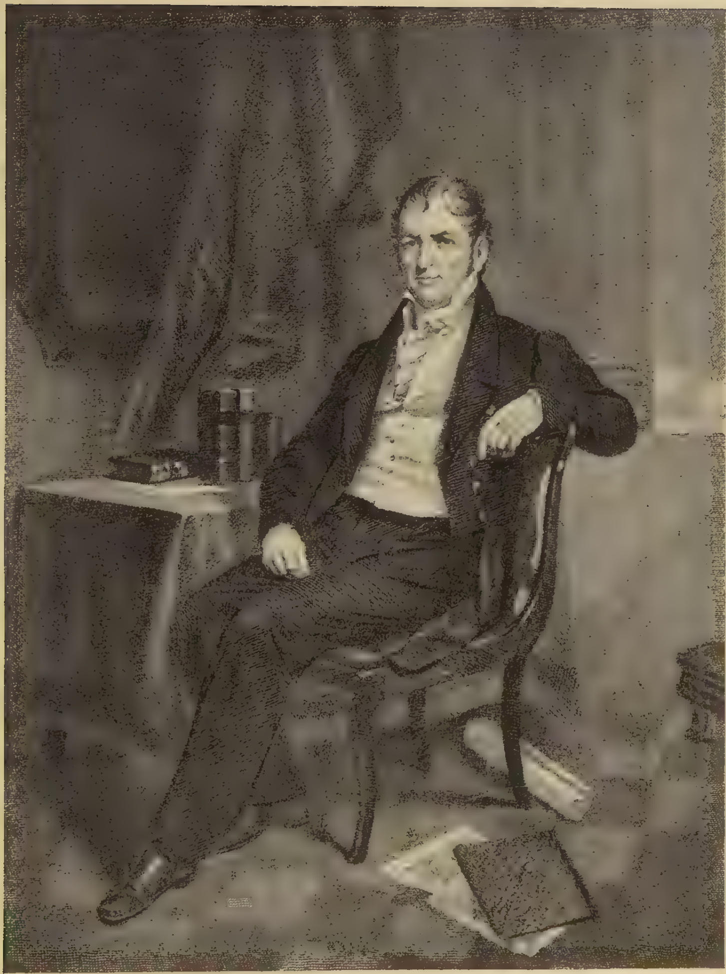
Pirates now filled the field, and the lawsuits which they were compelled to bring to defend themselves went against them. Miller wrote to Whitney on May 11, 1797, "The event of the first patent suit, after all our exertions made in such a variety of ways, has gone against us. The preposterous custom of trying civil causes of this intricacy and magnitude by a common jury, together with the imperfection of the patent law, frustrated all our views, and disappointed expectations which had become very sanguine. The tide of popular opinion was running in our favor, the judge was well disposed toward us, and many decided friends were with us, who adhered firmly to our cause and interests. The judge gave a charge to the jury pointedly in our favor; after which the defendant himself told an ac-

quaintance of his that he would give $2,000 to be free from the verdict, and yet the jury gave it against us, after a consultation of about an hour. And having made the verdict general, no appeal would lie.

"On Monday morning, when the verdict was rendered, we applied for a new trial, but the judge refused it to us on the ground that the jury might have made up their opinion on the defect of the law, which makes an aggression consist of making, devising, and using or selling; whereas we could only charge the defendant with using.

"Thus, after four years of assiduous labor, fatigue, and difficulty, are we again set afloat by a new and most unexpected obstacle. Our hopes of success are now removed to a period still more distant than before, while our expenses are realized beyond all controversy."

The failure of that patent suit loosed all the pirates, and Whitney saw the cotton fields flooded with gins, all of which were really based on his invention, and yet from which he did not receive one penny. The public had given over paying any attention to his patents. Every one seemed determined that a machine which meant so much to the cotton lands should be free to all, irrespective of any legal or moral rights in the matter. Miller wrote him a little later, "The prospect of making anything by ginning in this state is at an end. Surreptitious gins are erected in every part of the country, and the jurymen at Augusta have come to an understanding among themselves that they will never give a cause in our favor, let the merits of the case be as they may."



WHITNEY, THE INVENTOR OF THE COTTON GIN

Affairs could not well have been worse for the partners. They would have been willing to give up making gins and devote themselves to selling the rights they had already obtained, but it was difficult to find purchasers for titles which were so openly disregarded on every hand. They found it almost impossible to collect payments for the few machines they did sell, the buyers preferring to be sued, trusting to a jury of their neighbors deciding for them against the unpopular manufacturers, who claimed to control such an important machine as the gin. Whitney tried to sell his patent rights for South Carolina to that state itself, and had the matter brought before the Legislature. It met with better success than usual. "I have been at this place," he writes in a letter, "a little more than two weeks attending the Legislature. A few hours previous to their adjournment they voted to purchase for the state of South Carolina my patent-right to the machine for cleaning cotton at $50,000, of which sum $20,000 is to be paid in hand, and the remainder in three annual payments of $10,000 each." To this he added, "We get but a song for it in comparison with the worth of the thing, but it is securing something. It will enable Miller & Whitney to pay their debts and divide something between them."

This plan of selling the rights to the states seemed to promise better things for the inventor. In December, 1802, he arranged for the sale of similar rights to the state of North Carolina, and a little later a similar agreement was made with Tennessee. But imagine his dismay when the South Carolina Legislature sud-

denly annulled its contract with him, refused to make any further payments, and began suit to recover what had already been paid him. The current of popular opinion had again set against this firm of two. It was said that a man in Switzerland had invented a cotton-gin before Whitney, and that the main features of his own machine had been taken from others. But there were some upright and honorable men in the South Carolina Legislature, and they finally succeeded in convincing their associates that Whitney had been maligned. In the session of 1804 the Legislature rescinded its latest act in regard to the gin, and testified to its high opinion of Whitney.

The inventor's faithful partner, Miller, died in 1803. He had stood by Whitney through thick and thin, and had met one buffet after another. In spite of his splendid spirit the ceaseless war to protect their claims had somewhat broken him, and he had despaired of ever receiving justice in the courts. Whitney himself was now receiving some return from the sales to the states, and these enabled him to keep out of debt, but the greater part of his earnings had still to go for the costs of his suits at law.

In December, 1807, the United States Court in Georgia gave a decision in Whitney's favor against a man named Fort who had infringed on his patent. The words of Judge Johnson in this case became celebrated. "To support the originality of the invention," said he, "the complainants have produced a variety of depositions of witnesses, examined under commission, whose examinations expressly prove the origin, prog-

ress, and completion of the machine of Whitney, one of the copartners. Persons who were made privy to his first discovery testify to the several experiments which he made in their presence before he ventured to expose his invention to the scrutiny of the public eye. But it is not necessary to resort to such testimony to maintain this point. The jealousy of the artist to maintain that reputation, which his ingenuity has justly acquired, has urged him to unnecessary pains on this subject. There are circumstances in the knowledge of all mankind which prove the originality of this invention more satisfactorily to the mind than the direct testimony of a host of witnesses. The cotton-plant furnished clothing to mankind before the age of Herodotus. The green seed is a species much more productive than the black, and by nature adapted to a much greater variety of climate, but by reason of the strong adherence of the fibre to the seed, without the aid of some more powerful machine for separating it than any formerly known among us, the cultivation of it would never have been made an object. The machine of which Mr. Whitney claims the invention so facilitates the preparation of this species for use that the cultivation of it has suddenly become an object of infinitely greater national importance than that of the other species ever can be. Is it, then, to be imagined that if this machine had been before discovered, the use of it would ever have been lost, or could have been confined to any tract or country left unexplored by commercial enterprise? But it is unnecessary to remark further upon this subject. A number of years have elapsed

since Mr. Whitney took out his patent, and no one has produced or pretended to prove the existence of a machine of similar construction or use.

"With regard to the utility of this discovery the court would deem it a waste of time to dwell long upon this topic. Is there a man who hears us who has not experienced its utility? The whole interior of the Southern states was languishing and its inhabitants emigrating for want of some object to engage their attention and employ their industry, when the invention of this machine at once opened views to them which set the whole country in active motion. From childhood to age it has presented to us a lucrative employment. Our debts have been paid off, our capitals have increased, and our lands trebled themselves in value. We cannot express the weight of the obligation which the country owes to this invention. The extent of it cannot now be seen. Some faint presentiment may be formed from the reflection that cotton is rapidly supplanting wool, flax, silk, and even furs in manufactures, and may one day profitably supply the use of specie in our East India trade. Our sister states also participate in the benefits of this invention, for besides affording the raw material for their manufacturers, the bulkiness and quantity of the article afford a valuable employment for their shipping."

Whitney had fought long and hard, and had at last received at least partial justice. But it had been so slow in coming that, when his rights were to a certain extent established, there were only a few years left his patents to run. He had realized for some time that he

must look elsewhere for financial returns, and so, in 1798, had begun the manufacture of firearms. He purchased a site for his factory near New Haven, at a place called Whitneyville now, then known as East Rock. Oliver Wolcott, Secretary of the Treasury, ordered 10,000 stand of arms from him, and he contracted to furnish them. At first he met with many difficulties, owing to lack of proper materials and workmen, and his own lack of familiarity with the business. But as time went on the works improved, and Whitney applied his inventive genius to many important improvements. He received other contracts, and eventually the national government came to rely upon his factory for a large part of its war supplies.

In 1812 Whitney applied for a renewal of his patent for the cotton-gin. He set forth the facts that he had received almost no compensation for his invention, that it had made the fortune of many of the Southern states, that it enabled one man to do the work of a thousand men before, but that, placing the value of one man's labor at twenty cents a day, the whole amount he had received was less that the value of the labor saved in one hour by the use of his machines throughout the country. But again there was opposition from many influential Southern planters, and his application was denied.

The inventor was, however, making money from his factory for firearms, and his personal fortunes had brightened. In 1817 he married Henrietta Edwards, the daughter of Judge Pierpont Edwards, of Connecticut. His home life was ideally happy, he was fond of

New Haven, and eventually he received increasing evidence that the people of the cotton lands were learning their indebtedness to him, and were anxious to make some restitution for their earlier disregard of his claims. He died January 8, 1825.

The material value of Eli Whitney's invention can hardly be estimated. It opened a new kingdom to the South. It built up countless acres of hitherto unprofitable land. But in spite of men's recognition of the value of his cotton-gin, and their instant adoption of it everywhere, he was for years denied his title to it, and had to wage a warfare that is almost without parallel in the history of American inventors.

VII

FULTON AND THE STEAMBOAT
1765–1815

THERE is a peculiar charm attaching to the figure of Robert Fulton, the attraction that plays about the man who is many-sided, and picturesque on whatever side one looks at him. He was a man at home on both shores of the Atlantic, at a time when such men were rare. He had been taught drawing by Major André, when the latter was a prisoner of war in the little Pennsylvania town of Lancaster. He had hung out his sign as Painter of Miniatures at the corner of Second and Walnut Streets in Philadelphia, under the friendly patronage of Benjamin Franklin. He had lodged in London at the house of Benjamin West, and shown his pictures at the Royal Academy. Two great English noblemen became his allies in scientific studies. Napoleon, as First Consul, bargained with him over his invention of torpedoes. Finally he sent the little *Clermont* up the Hudson under steam. There was a man of rare ability, one who had many hostages to give to fortune. He was the artist turned inventor, as many another has done, and if he was not as great an artist as Leonardo da Vinci neither was Leonardo as great an inventor as Robert Fulton.

Fulton invented a machine for cutting marble, one for

spinning flax, a double inclined plane for canal navigation, a machine for twisting rope, an earth-scoop for canal and irrigation purposes, a cable-cutter, the earliest French panorama, a submarine torpedo boat, and the steamboat. Other men had worked over steamboats, but he reached the goal. He made the steamboat practicable, as Watt had the steam-engine. Above all, he was very fortunate; he found his countrymen ready to welcome the *Clermont*, and to fall in with his plans, an attitude which had not faced certain men in England and in France who had built similar boats earlier than Fulton. Some engineers have been tempted to call him a lucky amateur, a talented artist who happened to become interested in new methods of navigation. If one grants all this there is still the fact that it was the *Clermont's* success that opened the water-courses of the world to steam.

"Quicksilver Bob" he was called as a boy in Lancaster, because he used to buy all that metal he could for experiments. Even then he was many-sided. He made designs for firearms and experimented with guns to learn the carrying distance of various bores and balls. There was a factory in Lancaster where arms were being made for the Continental troops, and "Quicksilver Bob" was given the run of the place. In addition he painted signs to hang before the village shops and taverns.

To simplify his fishing expeditions he made a model of a boat propelled by paddles, and later he built such a boat and used it on the Conestoga River. No one could tell what he would turn to next. When Hessian

prisoners were kept in the neighborhood the town boys would go out to look at them, and Robert would make sketches of them. These sketches gave him a local reputation, and his friends were not surprised when at seventeen he left Lancaster to seek his fortune as a painter of portraits and miniatures in Philadelphia.

He was well liked in the city. He had a talent for friendship, which, combined with good looks, more than ordinary intelligence, and most uncommon industry, carried him far. He drew plans for machinery, he designed houses and carriages, he worked as professional painter. Franklin became his patron and adviser. Then illness sent him to the fashionable hot springs of Virginia, and there he heard so much talk of England and of France that he decided to see those countries for himself. Before he left America he bought a farm in Washington County, Pennsylvania, in order to insure a home for his mother and sisters. That done, he sailed for England, with a packet of letters of introduction, in 1786.

In London Fulton professed himself to be an artist, although his thoughts were constantly tending toward inventions. He lived at the house of Benjamin West, and painted, and his portraits were shown at the Royal Academy and at the Society of Artists. Betimes he enjoyed himself in society and in trips to the counties. He journeyed into Devonshire and stayed at Powderham Castle, copying famous pictures there. Wherever he went he made friends, and their influence was constantly helping him forward on what must have been a somewhat precarious career.

Two of these friends, the Duke of Bridgewater and the Earl of Stanhope, were scientists of repute. The Duke owned a great estate, of untold mineral wealth, which had never been properly worked because of lack of transportation facilities. He had recently built several canals on this property, and was at the head of a number of companies which were planning to intersect England with waterways. He interested Fulton in his schemes and gradually weaned his thoughts away from art to civil engineering. The Earl of Stanhope corresponded with him over the possibility of propelling boats by steam, and in these letters Fulton first gave the outlines of the plans he was later to perfect in the *Clermont*. The Earl was deeply interested, and encouraged the young American to persevere, but for the time Fulton left the steamboat to work out other problems.

The possibility of a great English canal system appealed to him strongly, and in 1794 he obtained an English patent for a double inclined plane for raising and lowering canal boats. Later he took English patents on a machine for spinning flax, and on a new device for twisting hemp rope. There followed others for a machine that should scoop out earth to make canals or aqueducts, for a "Market or Passage Boat" to use on canals, and for a "Dispatch Boat" that should travel quickly. He sent drawings of all these inventions to his influential friends, hoping that they would push them, and he also wrote and published "A Treatise on Canal Navigation." By this time he would seem to have given up all thought of the artist's ca-

reer, and to have turned his talent with the pen to the aid of his mechanical drawings.

The French Revolution was imminent, and Fulton was busy studying the conditions that were leading to it. He believed that Free Trade would tend to abolish many of the difficulties that divided nations, and he wrote a paper on that subject, addressed to the French Directory. He believed in democracy, but he was strongly of the opinion that the young American republic should take no part in the struggle for liberty in Europe. In a letter written in 1794 he says, "It has been much Agitated here whether the Americans would join the French. But I Believe every Cool friend to America could wish them to Remain nuter. The americans have no troublesome Neighbors, they are without foreign Possessions, and do not want the alliance of any Nation, for this Reason they have nothing to do with foreign Politics. And the Art of Peace Should be the Study of every young American which I most Sincerely hope they will maintain."

But Fulton himself was in a manner to be drawn into the turmoil. When France had quieted somewhat England began that policy of aggression on the sea toward American ships and crews that was to lead to the War of 1812. Fulton's attention was drawn from canal-building to the possibility of some invention that might tend to subserve peace, and this in time led him to design and build the first torpedo.

Again Fulton's talent for friendship stood him in good stead. When he had left London for Paris he

called upon Joel Barlow, poet and American diplomat, and was urged to take up his residence first at the hotel where the Barlows were staying, and later at their house. For seven years Fulton lived with them, busy about the most diverse matters, and always keenly interested in the struggles of the new and hot-tempered republic. A rich American had bought a tract of central real estate in Paris and had built a row of shops arranged on the two sides of a cloister. Fulton suggested that he add a panorama to the other buildings, and the idea was adopted. Fulton was given charge, and by 1800 he had built and opened the first panorama that Paris had ever seen. The show made money, and the inventor, a perfect Jack-of-all-trades, added another feather to his vari-colored cap.

In December, 1797, Fulton had interested his friend Barlow in a machine intended to drive "carcasses" of gunpowder under water. But his first experiments at exploding the gunpowder at a definite moment failed. Then he moved to Havre, where he would have greater opportunity to try out his torpedo-boats, as he christened them. His idea was that if his invention succeeded war would be made so dangerous that nations would be obliged to keep peace. Barlow was able to assist him with money until he had built and actually navigated some of his torpedoes along the coast. When he had satisfied himself, he wrote to the French government, the Directory, offering them his invention for use against their enemies.

The Directory was pleased with the offer, but the

government was in so much of a turmoil that it was months before any positive action was taken. At length, on February 28, 1801, Fulton received word from Napoleon, the First Consul, to send his torpedo-boat against the English fleet. He set out; but the English fleet did not come his way, and he spent the summer vainly reconnoitering along the coast. To show the value of his invention he arranged to attack a sloop. This he described in his letter to the French Commission on Submarine Navigation. "To prove this experiment," he wrote, "the Prefect Maritime and Admiral Villaret ordered a small Sloop of about 40 feet long to be anchored in the Road, on the 23rd of Thermidor. With a bomb containing about 20 pounds of powder I advanced to within 200 Metres, then taking my direction so as to pass near the Sloop, I struck her with the bomb in my passage. The explosion took place and the sloop was torn into atoms, in fact, nothing was left but the buye [buoy] and cable. And the concussion was so great that a column of Water, Smoke and fibres of the Sloop were cast from 80 to 100 feet in Air. This simple Experiment at once proved the effect of the Bomb Submarine to the satisfaction of all the Spectators."

This exhibition took place in August, 1801, before a crowd of onlookers, and at once established the value of the torpedo. But, as he was unable to attack any English ships, the French government lost interest in his invention, and Napoleon's scientific advisers reported to him that they regarded the young American as "a visionary."

At the same time the British government awakened to the great possibilities of Fulton's device. His old friend, Lord Stanhope, urged that suitable offers be made him. This was ultimately done, and in April, 1804, Fulton left France and returned to London. A contract was drawn up by which he was to put his torpedo at the service of the English government and receive in return two hundred pounds a month and one-half the value of all ships that might be destroyed by his invention.

This arrangement, however, was of short duration. A change of ministry dampened his hopes, and in 1806 the government declined to adopt his invention on his terms. At the same time they tried to suppress this new method of warfare, and to that end made him another offer. Fulton, always an ardent patriot, answered, "At all events, whatever may be your reward, I will never consent to let these inventions lie dormant should my Country at any time have need of them. Were you to grant me an annuity of £20,000 a year, I would sacrifice all to the safety & independence of my Country. But I hope that England and America will understand their mutual Interest too well to War with each other And I have no desire to Introduce my Engines into practice for the benefit of any other Nation."

He was already eager to return home to work upon his long cherished plans for a steamboat. He continues, "As I am bound in honor to Mr. Livingston to put my steamboat in practice and such engine is of more immediate use to my Country than Submarine Navigation, I wish to devote some years to it and

should the British Government allow me an annuity I should not only do justice to my friends but it would enable me to carry my steamboat and other plans into effect for the good of my Country.—It has never been my intention to hide these Inventions from the World on any consideration, on the contrary it has been my intention to make them public as soon as consistent with strict justice to all with whom I am concerned. For myself I have ever considered the interest of America [n] free commerce, the interest of mankind, the magnitude of the object in view and the rational reputation connected with it superior to all calculations of a pecuniary kind."

Satisfactory terms of agreement were reached, and in 1806 Fulton was free and ready to return to that native land from which he had been away twenty years.

The building of a practicable steamboat had long been in his mind. He had corresponded on the subject with Chancellor Livingston, who had devoted much time and money to new inventions. Fulton, when in Paris, had experimented with models of steamboats, and had studied the records of what had already been done in that line. In 1802 he had started a course of calculations on the resistance of water, and the comparative advantages of the known means of propelling vessels. He had rejected the plan of using paddles or oars, and also of forcing water out of the stern of the vessel, and had retained the idea of the paddle-wheel. This he tried successfully on a small model that he built and used on a river that ran through the village of Plombières. He then built an experimental boat, sixty-six

feet long and eight feet wide, and this he exhibited to a large audience of Parisians in August, 1803. His success led him to order certain parts of a steam-engine from the firm of Boulton and Watt in Birmingham, these to be shipped to America. Meantime Chancellor Livingston had obtained for himself and Fulton the exclusive right to navigate the waters of New York state by vessels propelled by fire or steam.

As soon as he reached America in December, 1806, Fulton started work on his boat. He engaged Charles Brownne, a ship-builder on the East River, to lay down the hull. He decided to name the vessel the *Clermont*, the name of Chancellor Livingston's country-place on the Hudson, where Fulton had been a guest. The engine duly arrived from Birmingham and was carried to the shipyard. As a number of loafers and hangers-on about the docks threatened injury to "Fulton's Folly," as the building boat was called, he had to engage watchmen to guard his property. By August the boat was finished, and was moved by her own engine from the yards to the Jersey shore. She was one hundred and fifty feet long, thirteen feet wide, and drew two feet of water. Before she had gone a quarter of a mile both passengers and observers on the shore were satisfied that the steamboat was a thoroughly practicable vessel.

On Sunday, August 9, 1807, Fulton made a short trial trip of the *Clermont*, and wrote an account of it to Livingston. "Yesterday about 12 o'clock I put the steamboat in motion first with a paddle 8 inches broad, 3 feet long, with which I ran about one mile up the East River against a tide of about one mile an

"The Clermont," the First Steam Packet

hour, it being nearly high water. I then anchored and put on another paddle 8 inches wide, 3 feet long, started again and then, according to my best observations, I went 3 miles an hour, that is two against a tide of one: another board of 8 inches was wanting, which had not been prepared, I therefore turned the boat and ran down with the tide—and turned her round neatly into the berth from which I parted. She answers the helm equal to anything that ever was built, and I turned her twice in three times her own length. Much has been proved by this experiment. First that she will, when in complete order, run up to my full calculations. Second, that my axles, I believe, will be sufficiently strong to run the engine to her full power. Third, that she steers well, and can be turned with ease."

It was on August 17, 1807, that the *Clermont* made her first historic trip up the Hudson. At one o'clock she cast off from her dock near the State's Prison, in what was called Greenwich Village, on the North River. The inventor described the voyage characteristically to a friend. He wrote, "The moment arrived in which the word was to be given for the boat to move. My friends were in groups on the deck. There was anxiety mixed with fear among them. They were silent, sad and weary. I read in their looks nothing but disaster, and almost repented of my efforts. The signal was given and the boat moved on a short distance and then stopped and became immovable. To the silence of the preceding moment, now succeeded murmurs of discontent, and agitations, and whispers and shrugs. I could hear distinctly repeated

—'I told you it was so; it is a foolish scheme: I wish we were well out of it.'

"I elevated myself upon a platform and addressed the assembly. I stated that I knew not what was the matter, but if they would be quiet and indulge me for half an hour, I would either go on or abandon the voyage for that time. This short respite was conceded without objection. I went below and examined the machinery, and discovered that the cause was a slight maladjustment of some of the work. In a short time it was obviated. The boat was again put in motion. She continued to move on. All were still incredulous. None seemed willing to trust the evidence of their own senses. We left the fair city of New York; we passed through the romantic and ever-varying scenery of the Highlands; we descried the clustering houses of Albany; we reached its shores,—and then, even then, when all seemed achieved, I was the victim of disappointment.

"Imagination superseded the influence of fact. It was then doubted if it could be done again, or if done, it was doubted if it could be made of any great value."

But the *Clermont*, in spite of all prophecies to the contrary, had traveled under her own steam from New York to Albany, and the trip was the crowning event in Fulton's career as inventor. At the time she made that first voyage the *Clermont* was a very simple craft, decked for a short distance at bow and stern, the engine open to view, and back of the engine a house like that on a canal-boat to shelter the boiler and provide an apartment for the officers. The rudder was of the pattern used on sailing-vessels, and was moved by

a tiller. The boiler was of the same pattern used in Watt's steam-engines, and was set in masonry. The condenser stood in a large cold-water cistern, and the weight of the masonry and the cistern greatly detracted from the boat's buoyancy. She was so very unwieldy that the captains of other river boats, realizing the danger of the steamboat's competition, were able to run into her, and make it appear that the fault was hers; and as a result she several times reached port with only a single wheel.

There were almost as many quaint descriptions of the boat as there were people who saw it. One described it as an "ungainly craft looking precisely like a backwoods sawmill mounted on a scow and set on fire." Others said the *Clermont* appeared at night like a "monster moving on the waters defying the winds and tide, and breathing flames and smoke." Some of the ignorant along the Hudson fell on their knees and prayed to be delivered from the monster. The boat must have been a very strange sight; pine wood was used for fuel, and when the engineer stirred the fire a torrent of sparks went shooting into the sky.

The boat was clumsy beyond question. The exposed machinery creaked and groaned, the unguarded paddle-wheels revolved ponderously and splashed a great deal of water, the tiller was badly placed for steering. Fulton quickly remedied some of the defects, and the *Clermont* that began to make regular runs from New York to Albany a little later was quite a different boat from that which made her maiden voyage on August 17th.

In spite of Fulton's gloomy tone in his letter there were many among the men and women who made the first trip with him who were not dubious concerning the invention. As soon as the first difficulties were overcome and the boat was moving on a steady keel, the passengers, most of whom were close friends of Fulton and of Chancellor Livingston, broke into song. As they passed by the Palisades it is said they sang "Ye Banks and Braes o' Bonny Doon." Fulton himself could not be overlooked. A contemporary described him: "Among a thousand individuals you might readily point out Robert Fulton. He was conspicuous for his gentle, manly bearing and freedom from embarrassment, for his extreme activity, his height, somewhat over six feet,—his slender yet energetic form and well accommodated dress, for his full and curly dark brown hair, carelessly scattered over his forehead and falling around his neck. His complexion was fair, his forehead high, his eyes dark and penetrating and revolving in a capacious orbit of cavernous depths; his brow was thick and evinced strength and determination; his nose was long and prominent, his mouth and lips were beautifuly proportioned, giving the impress of eloquent utterance. Trifles were not calculated to impede him or damp his perseverance."

Fulton was now forty-two years old, and famous on both sides of the Atlantic. He asked Harriet Livingston, a near relation of his friend the Chancellor, to become his wife. She accepted him, and he was warmly welcomed into that rich and influential family.

On September 2, 1807, Fulton advertised regular

sailings of the *Clermont* between New York and Albany. These proved popular, and other routes were soon planned. That winter he made many changes in the vessel and worked out certain devices that he wished to patent. The name of *Clermont* was changed to the *North River* the following spring, and the reconstructed steamboat continued in regular service on the Hudson for a number of years. In the succeeding year he built other boats, the *Rariton*, to run from New York to New Brunswick, and *The Car of Neptune* as a second Hudson River boat. He was very much occupied perfecting new commercial schemes, protecting his patents from a horde of pirates, and planning to introduce his invention into Europe. Before his death in 1815, eight years after the *Clermont's* first trip, he had built seventeen boats, among them the first steam war frigate, a torpedo boat, and the first steam ferry-boats with rounded ends to be used for approaching opposite shores.

A century has not dimmed Fulton's fame, nor set aside his claim to be the practical inventor of the steamboat. He built the first one to be used in American waters, and his model was copied in all other countries. He carried his ideas to completion, and that, with his talent to observe and improve upon other men's work, gave him his leading place among the world's pioneers.

VIII

DAVY AND THE SAFETY-LAMP
1778–1829

HUMPHREY DAVY, according to his contemporaries, could have chosen any one of several roads to fame. Samuel Taylor Coleridge said of him, "Had not Davy been the first chemist, he probably would have been the first poet of his age." Among many activities he invented the safety-lamp, the object of which was to protect miners from the perils of exploding fire-damp. George Stephenson invented a similar device at about the same time, or a little earlier, but Davy's lamp was the one most generaly adopted, and his claim as inventor is commonly recognized, while Stephenson's fame is secure with the perfection of the steam-locomotive and the railroad.

Davy was born at Penzance in Cornwall December 17, 1778, the eldest son in a family of five children. More alert and imaginative than other boys, and with an uncommonly good memory, he made great headway at Mr. Coryton's grammar school, where he went when he was six. Coleridge's opinion of him may have been correct, for history says that he was a fluent writer of English and Latin verses while still a schoolboy, and that he could tell stories well enough to hold an audience of his teachers and neighbors. He liked fine

language and the arts of speech, and, according to his brother, Dr. John Davy, he cultivated those arts in his walks. Once when he was taking a bottle of medicine to a sick woman in the country he began to declaim a stirring speech, and at its climax threw the bottle away. He never noticed its loss until he reached the patient, and then wondered what could have become of the vial. The bottle was found next morning in a hay-field adjoining the path Davy had taken.

When he was fourteen he left Mr. Coryton's school for the Truro Grammar School, where he stayed for a year. Here he was famed for his good-humor and a very original turn of mind. A school friend, reminiscing about Humphrey, told of a walk several of them took one hot day. "Whilst others complained of the heat," said he, "and whilst I unbuttoned my waistcoat, Humphrey appeared with his great-coat close-buttoned up to his chin, for the purpose, as he declared, of keeping *out* the heat. This was laughed at at the time, but it struck me then, as it appears to me now, as evincing originality of thought and an indisposition to be led by the example of others."

This originality of thought and love of experiment for its own sake were to be chief characteristics of the future scientist.

His school education was finished when he was fifteen, and he returned home, where he studied French in a desultory fashion, and devoted most of his time to fishing, of which he was always very fond. His father's death made him realize that as the eldest of the sons he must shoulder the responsibility for the family's

support, and, all his natural tastes lying in that direction, he decided to become a physician.

A practicing surgeon and apothecary of Penzance, Bingham Borlase, was willing to take Davy as an apprentice, and the youth began work and study in his office. But the boy was no ordinary apprentice. He became almost at once an omnivorous student and writer. He laid out a plan of study that included theology, astronomy, logic, mathematics, Latin, Greek, Italian, Spanish, and Hebrew, and he wrote essays, remarkably mature and well-phrased, in a series of note-books that he kept in the office. Poetry he wrote also, filled with love of the sea that circled his native Cornwall, and the great cliffs and moorlands that make that part of England one of the most picturesque spots in the world.

His work with Mr. Borlase brought him into the field of chemistry when he was nineteen. It was a field of magic to him. He read two books, Lavoisier's "Elements of Chemistry," and Nicholson's "Dictionary of Chemistry," and rushed from them to experiment for himself. His bedroom was his laboratory. His tools were old bottles, glasses, tobacco-pipes, teacups, and such odds and ends as he could find. When he needed fire he went to the kitchen. The owner of the house, Mr. Tonkin, was an old friend of the Davy family, and very fond of Humphrey, but the amateur experiments were almost too much for him. Said he, after he had watched some more than usually noisy combustion at the fire, "This boy, Humphrey, is incorrigible. Was there ever so idle a dog? He

will blow us all into the air." But Humphrey minded no arguments nor objections; he was studying the effects of acids and alkalies on vegetable colors, the kind of air that was to be found in the vesicles of common varieties of seaweed, and the solution and precipitation of metals. The work was all-engrossing; it occupied every spare moment of his time and thought.

If any greater stimulus to scientific study had been needed it would have been supplied to young Davy by his acquaintance with Gregory Watt, the son of the inventor James Watt. Gregory came to board at Mrs. Davy's house when he was twenty-one, and Humphrey nineteen. He was a splendid companion, and possessed of a remarkably brilliant mind. In a short time the two youths had become inseparable friends, experimenting together, and taking walks to the mines and quarries in the neighborhood of Penzance in search of minerals for study. It was an ideal friendship, incomparably valuable for Davy. But Gregory Watt died when he was twenty-eight. "Gregory was a noble fellow," Davy wrote to a friend, "and would have been a great man."

In the meantime the young physician's apprentice had been lured away from Penzance. Dr. Beddoes had established what he styled a Pneumatic Institution at Clifton, the object of which was to try the medicinal effects of different gases on consumptive patients. Davy, only twenty, had been offered the position of director, and had accepted. His old friend Mr. Tonkin, who had thought to see Humphrey become the leading

physician of Penzance, was so much put out with this change of plan that he altered his will and revoked a legacy he had intended for Davy.

Filled with the ardor of research Davy went on with his experiments at Clifton. He discovered silica in the epidermis of the stems of weeds, corn, and grasses. He experimented with nitrous oxide (laughing gas) for ten months until he had thoroughly learned its intoxicating effects. Often he jeopardized his life, and once nearly lost it, by breathing carburetted hydrogen. He published the results of his more important experiments. When he was twenty-one he issued his "Essays on Heat and Light." He experimented with galvanic electricity, and increased the powers of Volta's Galvanic Pile. Moreover he outlined and partly drafted an epic poem on the deliverance of the Israelites from Egypt. The total is a surprising catalogue of industries for the young Clifton Director.

His ardor had worn him out, and he was forced to take a holiday at Penzance. His reputation as a rising scientist had reached the little Cornish town, and he was given a hearty welcome. He loved his own country and never lost his delight in her natural beauties. Nor did he ever forget his own days in the grammar school, and in his will he directed that a certain sum of money should be paid to the master each year "on condition that the boys may have a holiday on his birthday."

Davy had already made influential friends, and one of them, Dr. Hope, the professor of chemistry at the University of Edinburgh, was to give him his next step

forward. Dr. Hope knew Davy's works on heat, nitrous oxide, and galvanic electricity, and he recommended the young scientist to Count Rumford for the professorship of chemistry in the Royal Philosophical Institution in London, which Count Rumford had been instrumental in founding. Davy wrote to his mother that this was "as honorable as any scientific appointment in the kingdom, with an income of at least five hundred pounds a year."

He went to London in 1801, and there he had the great satisfaction of meeting many scientific men whose names and work were well known to him. Six weeks after he arrived he began his first course of lectures, taking for his subject the history of galvanism, and the various methods of accumulating galvanic influence. The *Philosophical Magazine* said of the new lion, "The sensation created by his first course of lectures at the Institution, and the enthusiastic admiration which they obtained, is at this period hardly to be imagined. Men of the first rank and talent,—the literary and the scientific, the practical and the theoretical,—blue-stockings and women of fashion, the old and the young, all crowded, eagerly crowded, the lecture-room. His youth, his simplicity, his natural eloquence, his chemical knowledge, his happy illustrations and well-conducted experiments, excited universal attention and unbounded applause. Compliments, invitations, and presents were showered upon him in abundance from all quarters; his society was courted by all, and all appeared proud of his acquaintance."

Davy was an eloquent, enthusiastic, forceful speaker.

He prepared his lectures with the greatest care, and he delivered them with that attention to dramatic effect which is instinctive in all really great speakers. Coleridge said, "I attend Davy's lectures to increase my stock of metaphors," and there were many others who went to hear the young chemist for other reasons than a liking for science. He had his own theories of the arts of public address. "Great powers," said he, "have never been exerted independent of strong feelings. The rapid arrangement of ideas from their various analogies to the equally rapid comparisons of these analogies, with facts uniformly occurring during the progress of discovery, have existed only in those minds where the agency of strong and various motives is perceived—of motives modifying each other, mingling with each other, and producing that fever of emotion which is the joy of existence and the consciousness of life."

In addition to his lectures Davy worked hard in the well-stocked laboratory of the Institution, where he was supplied with a corps of capable assistants. His researches covered a very large part of the field of chemistry, and he was indefatigable in running down any new idea which his active brain chanced to hit upon. In his vacations from London he went to the farthest regions of the British Isles, spending considerable time in the north of Ireland and the Hebrides. Here he studied the geological structures, and collected all the information he could in regard to agriculture. Anything to do with natural science interested him. He sketched a great deal, and he was forever asking ques-

tions of all the countrymen he met. His questions made him famous in many a hamlet, where such inquisitiveness had never been known before.

Shortly after he had moved to London he had been asked to investigate astringent plants in connection with tanning. To this end he visited tan-yards and farmers, and in 1802 began to deliver a course of lectures on "The Connection of Chemistry with Vegetable Physiology." These lectures proved remarkably popular, and for ten years he repeated them at the meetings of the Board of Agriculture. They were later published in book form, and so great was their interest that they were translated into almost every European language. *The Edinburgh Review*, that dean of British critics, said, "We feel grateful for his having thus suspended for a time the labors of original investigation, in order to apply the principles and discoveries of his favorite science to the illustration and improvement of an art which, above all others, ministers to the wants and comforts of man."

When his agricultural researches were finished he went back to his studies with the voltaic pile or battery. He discovered that potash and soda can be decomposed, with the resultant metals of potassium and sodium. When he made this discovery he was so delighted that he danced about the room, and was too excited to finish the experiment for some time.

He had worked too hard, and soon after this discovery he fell ill. For days all London watched for the bulletins of the young chemist's condition. Fortunately he recovered, and in time went back to the

work which was proving so invaluable for the world of science.

The Royal Institution now provided him with a voltaic battery that was four times as powerful as any that had previously been constructed. With this he made numberless chemical discoveries. The Royal Society had made him a fellow when he was twenty-five years old, and one of its secretaries when he was twenty-nine. His London lectures grew continually more popular. The Dublin Society invited him to lecture in that city, and his course at once attracted the greatest attention. He was already the scientific lion of England, but withal a very modest and unassuming lion. Cuvier said, "Davy, not yet thirty-two, in the opinion of all who could judge of such labors, held the first rank among the chemists of this or of any other age." The National Institute of France awarded him the prize that had been established by Napoleon for the greatest discovery made by means of galvanism. Then, in 1812, when he was thirty-three, he was knighted by the Prince Regent.

Sir Humphrey Davy, as he now was, married Mrs. Appreece, a woman of many talents and unusual intelligence. She was rich, and soon after their marriage Davy was able to resign his professorship at the Royal Institution, which he had held for twelve years, and devote himself to original research and to travel. Carrying a portable chemical apparatus for his studies, Sir Humphrey and Lady Davy went first to Scotland, and then to France, Italy, and Germany. They met the most prominent men of the age in those countries.

These men found the famous chemist interested in everything about him, as much of a poet as a scientist. In Rome he wrote a sonnet to the sculptor Canova, and the literary circles of Italy proclaimed him a poet after their own heart.

Davy was now one of the foremost chemists of the world, but he could as yet hardly lay claim to the title of inventor. He had been an ambitious man, and had once said that he had escaped the temptations that lay in wait for many men because of "an active mind, a deep ideal feeling of good, and a look toward future greatness." That future greatness had always been in his thoughts, and had been one of the compelling powers in his great chemical discoveries. But beyond this thought of greatness was a very deep and earnest desire to help his fellow men. So when the chance to do this offered he took advantage of it at once.

Explosions of coal-gas were only too common in the mines of England. They were almost always fatal to the miners, and formed the greatest peril of those who labored underground. In 1812 a terrible explosion occurred in a leading English mine, and caused the death of almost a hundred miners. The mine had caught on fire, and had to be closed at the mouth, which meant certain destruction to those within. The catastrophe was so great that the biggest mine-owners met to see whether some protection against such accidents could not be devised. After much discussion they appointed a committee to call on Sir Humphrey Davy and ask him to investigate the possibilities for them.

Davy realized that here lay his opportunity to be of

real service to men, the goal he had always had in mind. He took up the question, experimented with fire-damp, and found that it was in reality light carburetted hydrogen. He visited many mines, and took into careful consideration the conditions under which the men worked. For months he investigated and experimented, and at length, in 1815, he constructed what he called the safety-lamp. This was an oil lamp which had a chimney or cage of wire gauze. The gauze held the flame of the lamp from passing through and igniting the fire-damp outside. It was only possible for a very little of the fire-damp to penetrate the gauze and such as did was held harmless prisoner. The cage allowed air to pass and light to escape, and although by the combustion of the fire-damp the wire gauze might become red hot, it was still efficient as a safety-lamp.

Davy's safety-lamp proved exactly what was needed to act as protection from exploding fire-damp. It was tried under all conditions and served admirably. George Stephenson had worked out a somewhat similar safety-lamp at about the same time, and his was used in the collieries around Newcastle. In the rest of England Davy's lamp was at once adopted. All miners were equipped with either the Davy lamp or the "Geordie" lamp, as the other was called, and the mine fatalities from fire-damp immediately decreased. This lamp is still the main safeguard of those who have to contend with dangerous explosive gases in mines all over the world.

Friends urged Davy to patent his lamp, and thus

THE DAVY SAFETY LAMP

ensure himself a very considerable income from its sale. But he said, "I never thought of such a thing: my sole object was to serve the cause of humanity; and if I have succeeded, I am amply rewarded in the gratifying reflection of having done so. I have enough for all my views and purposes; more wealth could not increase either my fame or my happiness. It might undoubtedly enable me to put four horses to my carriage; but what would it avail me to have it said that Sir Humphrey drives his carriage and four?"

His fellow men appreciated the great value of this service he had rendered. At Newcastle, the centre of the mining country, a dinner was given in his honor, and a service of plate, worth over twelve thousand dollars, was presented to him. The Emperor of Russia sent him a magnificent silver-gilt vase, with a letter congratulating him on his great achievement, and the King of England made him a baronet.

Davy himself, in spite of his reputation as a chemist, placed this invention above all his other work. "I value it more than anything I ever did," said he. "It was the result of a great deal of investigation and labor; but if my directions be attended to, it will save the lives of thousands of poor men. I was never more affected than by a written address which I received from the working colliers when I was in the north, thanking me on behalf of themselves and their families for the preservation of their lives."

Davy's note-books are most interesting reading and show the philosophic trend of his thoughts. At one time he said, "Whoever wishes to enjoy peace, and is

gifted with great talents, must labor for posterity. In doing this he enjoys all the pleasures of intellectual labor, and all the desire arising from protracted hope. He feels no envy nor jealousy; his mark is too far distant to be seen by short-sighted malevolence, and therefore it is never aimed at. . . . To raise a chestnut on the mountain, or a palm in the plain, which may afford shade, shelter, and fruit for generations yet unborn, and which, if they have once fixed their roots, require no culture, is better than to raise annual flowers in a garden, which must be watered daily, and in which a cold wind may chill or too ardent a sunshine may dry. . . . The best faculties of man are employed for futurity: speaking is better than acting, writing is better than speaking."

He was fond of travel, and after he had seen the successful use of his lamp he went abroad again. When he returned he was made president of the Royal Society, a position which had been made illustrious by Sir Isaac Newton. The British navy asked him to discover what could be done to prevent the corrosion of copper sheathing on vessels, caused by salt water. He made experiments, and at last succeeded in rendering the copper negatively electrical by the use of small pieces of tin, zinc, or iron nails. But shells and sea-weed would adhere to the non-corroded surface, and hence the process was not entirely successful. This principle of galvanic protection, however, was found to be applicable to many other purposes.

These and other experiments in chemistry and electricity, travel, and his duties as president of the

Royal Society filled his days. In 1826 he was attacked by paralysis, and from then he spent much of his time on the continent, seeking health and strength. He wrote on fishing and on travel, and all his writings, on whatever theme he touched, are filled with the love of nature and of beauty, and permeated with that philosophic balance that had been characteristic of his whole career. He died in Geneva, May 29, 1829.

Davy was not the born inventor, drawn irresistibly to construct something new. He was the born chemist, and it was only when he was asked to investigate the nature of the fire-damp that he fell to studying whether some adequate protection could not be afforded the miners. Yet he himself said that he was more proud of his safety-lamp than of all his other discoveries, and although the scientists and chemists may think of Humphrey Davy as a great experimenter, great lecturer, and great writer on chemistry and electricity, the world at large knows him best for his safety-lamp and for the great change for the better he was able to bring about in the mines of England.

IX

STEPHENSON AND THE LOCOMOTIVE
1781–1848

THE need of finding a new way of working the coal mines of England, and of marketing the coal, which had been such an important factor in the development of the steam-engine, was a scarcely less important factor in the building of the earliest practical railway locomotive. The coal had to be hauled from the pit of the colliery to the shipping place. It was carried in cars that were pushed or pulled over a rude line of wooden or iron rails. But it was evident from the time when James Watt began to build his steam-engines to lift the coal from the mine that men of inventive minds would soon seek to send the cars over the level ground by the same power. We owe the railroad chiefly to the needs of the north of England, and there we find the real birth of the locomotive.

About the beginning of the nineteenth century a number of men in England were experimenting with new means of locomotion, both for merchandise and for passengers. Their projects varied from cars running on wheels and drawn by horses to carriages propelled by small stationary steam-engines, placed at short distances from each other along the road. In

1802 Richard Trevethick, a captain in a Cornish tin-mine, took out a patent for a steam-carriage. The machine he built looked like an ordinary stage-coach on four wheels. It had one horizontal cylinder, which was placed in the rear of the hind axle, together with the boiler and the furnace-box. The motion of the piston was carried to a separate crank-axle, and that in turn gave the motion to the axle of the driving-wheel. This was in itself a great invention, being the first really successful high-pressure engine that was built on the principle of moving a piston by the elasticity of steam against only the pressure of the air. The steam was admitted from the boiler under the piston that moved in a cylinder, and forced it upward. When the motion had reached its limit, the communication between the piston and the under side of the cylinder was shut off, and the steam escaped into the atmosphere. Then a passage was opened between the boiler and the upper end of the piston, which was consequently pushed downward, and then the steam was again allowed to escape. As a result the power of the engine was equal to the difference between the atmosphere's pressure and the elastic force of the steam in the boiler.

This steam-carriage of Trevethick was fairly successful, and created a great sensation in that part of Cornwall where it was built. He decided to take it to London, and drove it himself to Plymouth, from which port it was to be carried by sea. On the road it caused amazement and consternation, and won the name of Captain Trevethick's dragon. He exhibited

it in London, but after a short time gave up driving it, believing that the roads of England were too badly built to make the use of a steam-carriage feasible.

Other men were working on similar lines. Among them was the owner of a colliery in the north named Blackett, who built a number of engines for propelling coal-cars and used them at his mines. But these were very clumsy and heavy, moved slowly, and had to be continually repaired at considerable expense, so that other miners, after examining Blackett's engines, decided they were not worth the cost of manufacture. To make the steam-carriage really serviceable it must be more efficient and reliable.

Meantime a young man named George Stephenson, who was working at a coal mine at Killingworth, seven miles north of Newcastle, was studying out a new plan of locomotive. His father had been a fireman in a colliery at Wylam, a village near Newcastle, and there the son George was born on June 9, 1781. He had lived the life of the other boys of the village, had been a herd-boy to care for a neighbor's cows, had been a "picker" in the colliery, and separated stones and dross from the coal, had risen to assistant fireman, then fireman, then engineman. He was strong and vigorous, fond of outdoor sports, and also considerable of a student. In time he moved to Willington Quay, a village on the River Tyne, where coal was shipped to London. Here he married, and made his home in a small cottage near the quay. He was in charge of a fixed engine on Willington Ballast Hill that drew the trains of laden coal-cars up the incline.

After he had worked for three years at Willington he was induced to take the position of brakesman of the engine at the West Moor Colliery at Killingworth. He had only been settled in his new place a short time when his wife died, leaving him with a son Robert. Stephenson thenceforth threw himself into his work harder than ever, studying with his son as the boy grew older, and spending a great deal of time over his plans for a steam-engine that should move the coal-cars. He knew the needs of the colliery perfectly, had acquired a good knowledge of mechanics, and proposed to put his knowledge to account.

He had already, as engine-wright of the Killingworth Colliery, applied the surplus power of a pumping steam-engine to the work of drawing coal from the deeper workings of the mine, thereby saving a great amount of manual and horse labor. When the coal was drawn up it had to be transported to the quays along the Tyne, and to simplify this Stephenson laid down inclined planes so that a train of full wagons moving down the incline was able to draw up another train of empty wagons. But this would only work over a short distance, and was in itself a small saving in effort.

The engines that Mr. Blackett had built, using Trevethick's model as a basis, were working daily near the Killingworth Colliery, and Stephenson frequently went over to see them. He studied Mr. Blackett's latest locomotive, nicknamed "Black Billy," with the greatest care, and then told his friend Jonathan Foster that he was convinced that he could build a better engine than

Trevethick's, one that would work more effectively and cheaply and draw a train of cars more steadily.

He also had the advantage of seeing other primitive locomotives that were being tried at different places near Newcastle. One of these, known as Blenkinsop's Leeds engine, ran on a tramway, and would draw sixteen wagons with a weight of seventy tons at the rate of about three miles an hour. But the Blenkinsop engine was found to be very unsteady, and tore up the tram-rails, and when its boiler blew up the owner decided that the engine was not worth the cost of repair. Stephenson, however, drew some useful points from it, as well as from each of the other models he saw, and proposed to himself to follow Watt's example in constructing his steam-engine, namely, to combine the plans and discoveries of other inventors in a machine of his own, and so achieve a more complete success.

Stephenson was now very well regarded at the colliery for the improvements he had made there. He brought the matter of building a new "Traveling Engine," as he called it, to the attention of the lessèes of the mine in 1813. Lord Ravensworth, the principal partner, formed a favorable opinion of Stephenson's plans, and agreed to supply him with the funds necessary to build a locomotive.

With his support Stephenson went to work to choose his tools and workmen. He had to devise and make many of the tools he needed, and to train his men specially for this business. He built his first engine in the workshops at the West Moor Mine. It followed to some extent the model of Blenkinsop's engine. It had

a cylindrical boiler, eight feet long and thirty-four inches in diameter, with an internal flue tube passing through it. The engine had two vertical cylinders and worked the propelling gear with cross-heads and connecting-rods. The power of the two cylinders was carried by means of spur-wheels, which continued the motive power to the wheels that supported the engine on the rails. The engine was simply mounted on a wooden frame that was supported on four wheels. These wheels were smooth, as Stephenson was convinced that smooth wheels would run properly on an edge-rail.

This engine, christened the "Blutcher," and taking about ten months to build, was tried on the Killingworth Railway on July 25, 1814. It proved to be the most successful working engine that had yet been built, and would pull eight loaded wagons of about thirty tons' weight up a slight grade at the rate of four miles an hour. For some time it was used daily at the colliery.

But the "Blutcher" was after all a very clumsy machine. The engine had no springs, and its movement was a series of jolts, that injured the rails and shook the machinery apart. The important parts of the machinery were huddled together, and caused friction, and the cog-wheels soon became badly worn. Moreover the engine moved scarcely faster than a horse's walk, and the expense of running it was very little less than the cost of horse-power. Stephenson saw that he must in some way increase the power of his engine if he was to provide a new motive power for the mines.

In this first engine the steam had been allowed to escape into the air with a loud, hissing noise, which frightened horses and cattle, and was generally regarded as a nuisance. Stephenson thought that if he could carry this steam, after it had done its work in the cylinders, into the chimney by means of a small pipe, and allow it to escape in a vertical direction, its velocity would be added to the smoke from the fire, or the rising current of air in the chimney, and would in that way increase the draught, and as a result the intensity of combustion in the furnace. He tried this experiment, and found his conjecture correct; the blast stimulated combustion, consequently the capability of the boiler to generate steam was greatly increased, and the power of the engine increased in the same proportion. No extra weight was added to the machine. The invention of this steam blast was almost the turning point in the history of the locomotive. Without it the engine would have been too clumsy and slow for practical use, but with it the greatest possibilities of use appeared.

Encouraged by the success of his steam blast Stephenson started to build a second locomotive. In this he planned an entire change in mechanical construction, his principal objects being the use of as few parts as possible, and the most direct possible application of power to the wheels. He took out a patent for this engine on February 28, 1815. This locomotive had two vertical cylinders that communicated directly with each pair of the four wheels that supported the engine, by means of a cross-head and a pair of connecting-

rods. "Ball and socket" joints were used to make the union between the ends of the cross-heads where they united with the connecting-rods, and between the rods and the crank-pins attached to each driving-wheel. The mechanical skill of his workmen was not equal to the forging of all the necessary parts as Stephenson had devised them, and he was obliged to make use of substitutes which did not always work smoothly, but he finally succeeded in completing a locomotive which was a vast improvement on all earlier ones, and that was notable for the simple and direct communication between the cylinders and the wheels, and the added power gained by using the waste steam in the steam blast. This second locomotive of Stephenson's was in the main the model for all those built for a considerable time.

During the time when Stephenson was working on his second locomotive explosions of fire-damp were unusually frequent in the coal mines of Northumberland and Durham, and for a space he turned his attention to the possibility of inventing some pattern of safety-lamp. The result was his perfection of a lamp that would furnish the miners with sufficient light and yet preclude risk of exploding fire-damp. This came to be known as the "Geordie Lamp," to distinguish it from the "Davy Lamp" that Sir Humphrey Davy was inventing at about the same time. The lamp was used successfully by the miners at Killingworth, and was considered by many as superior to Davy's lamp. Disputes arose as to which was invented first, and long controversies between scientific societies, most of which sided with the friends of Davy. Stephenson himself

stated his claims firmly, but without rancor, and when he saw that it prevented the accidents in mines was satisfied that he had gained his object, and returned to the more absorbing subject of locomotives.

He realized that the road and the rails were almost as important as the engine itself. At that time the railways were laid in the most careless fashion, little attention was paid to the rails' proper joining, and less to the grades of the roads. Stephenson laid down new rails at Killingworth with "half-lap joints," or extending over each other for a certain distance at the ends, instead of the "butt joints" that were formerly used. Over these both the coal-cars drawn by horses and his locomotive ran much more smoothly. To increase this smoothness of travel he added a system of spring carriage to his engine, and saved it from the jolting that had handicapped his first model.

The second locomotive was proving so efficient at the Killingworth Colliery that friends of the inventor urged him to look into the possible use of steam in traveling on the common roads. To study this he made an instrument called the dynamometer, which enabled him to calculate the resistance of friction to which carriages would be exposed on railways. His experiments made him doubtful of the possibility of running such railroads, unless a great amount of very expensive tunneling and grading were first done.

All this time George Stephenson continued to study with his son Robert. The boy was employed at the colliery, and was rapidly learning the business under the skilful charge of his father. Stephenson had de-

cided however that Robert should have a better education than had been his, and in 1820 took him from his post as viewer in the West Moor Pit, and sent him to the University of Edinburgh.

News spread slowly in England in that day, and the fact that a steam locomotive was being successfully used at Killingworth attracted very little attention in the rest of the country. Even in the neighborhood of the mines people soon grew used to seeing "Puffing Billy," as the engine was called, traveling back and forth from the pit to the quay, and took it quite for granted. Here and there scattered scientific men, ever since Watt's perfection of the steam-engine, had considered the possibility of travel by steam, but practical business men had failed to come forward to build a railway line. At length, however, Edward Pease, of Darlington, planned a road to run from Stockton to Darlington, and set about building it. He had a great deal of difficulty in forming a company to finance it, but he was a man of much perseverance, and at length he succeeded. While he was doing this Stephenson was patiently building new locomotives, and trying to induce the mine-owners along the Tyne to replace their horse-cars with his engines. In 1819 the owners of the Hetton Colliery decided to make this change, and asked Stephenson to take charge of the construction of their line. He obtained the consent of the Killingworth owners, and began work. On November 18, 1822, the Hetton Railway was opened. Its length was about eight miles, and five of Stephenson's locomotives were working on it, under the direction of his brother

Robert. In building this line George Stephenson was thoroughly practical. Although he knew that his name was becoming more and more identified with the locomotive engine, he did not hesitate to use stationary engines wherever he considered that they would be more economical. In the Hetton Railway, which ran for a part of its distance through rough country, he used stationary engines wherever he could not secure grades that would make locomotives practicable. His own steam-engines traveled over this line at the rate of about four miles an hour, and each was able to draw a train of seventeen coal wagons, weighing about sixty-four tons.

The coal mines of the Midlands and the north of England had been the original inducement to inventors to build engines that would draw cars, and the manufacturing needs of Manchester and Liverpool were now gradually inducing promoters to consider building railroads. The growth of Manchester and the towns close to it was tremendous, the cotton traffic between Manchester and Liverpool had jumped to enormous figures, and men felt that some new method of communication must be found. Robert Fulton's friend, the Duke of Bridgewater, had been of some help with his canal system, but the trade quickly outstripped this service. Then William James, a man of wealth and influence, a large landowner and coal-operator, took up the subject of a Liverpool and Manchester Railway with some business friends, and had a survey of such a line begun. His men met with every possible resistance from the country people, who had

no wish to have " Puffing Billys " racing through their fields; bogs had to be crossed and hills leveled; and it soon appeared that the cost of a road would be very expensive. The local authorities gave James and his associates some encouragement, but those members of Parliament he approached were more or less opposed to his plans. The time was not yet quite ripe for the road, but the needs of trade were growing more and more pressing.

Meantime Mr. Pease was again growing eager to build his Darlington and Stockton line. Near the end of the year 1821 two men called at his house. One introduced himself as Nicholas Wood, viewer at Killingworth, and then presented his companion, George Stephenson, of the same place. Stephenson had letters to Mr. Pease, and after a talk with him, persuaded him to go to the Killingworth Colliery and see his locomotives. Pease was much impressed with the engines he saw there, and even more with Stephenson's ability as a practical engineer. The upshot of the matter was that Pease reported the results of his visit to the directors of his company, and they authorized him to secure Stephenson's services in surveying the line they wished to build. He took up the work, made careful surveys and reports, and was finally directed to build a railway according to his own plans. This he did, working with the best corps of assistants and the most efficient materials he could find. When the line was nearly completed he made a tour of inspection over it with his son and a young man named John Dixon. Dixon later recalled that Stephenson said to the two as they

came to the end of their trip, "Now, lads, I will tell you that I think you will live to see the day, though I may not live so long, when railways will come to supersede almost all other methods of conveyance in this country —when mail coaches will go by railway, and railroads will become the Great Highway for the king and all his subjects. The time is coming when it will be cheaper for a working man to travel on a railway than to walk on foot. I know there are great and almost insurmountable difficulties that will have to be encountered; but what I have said will come to pass as sure as we live."

In spite of the powerful opposition that the company encountered, and the threats of the road trustees and others, the Stockton and Darlington line was opened for travel on September 27, 1825. A great concourse of people had gathered to see the opening of this first public railway. Everything went well. Stephenson himself drove the engine, and the train consisted of six wagons, loaded with coal and flour, then a special passenger coach, filled with the directors and their friends, then twenty-one wagons temporarily fitted with seats for passengers, and then six wagons of coal, making thirty-four carriages in all. A contemporary writer says, "The signal being given the engine started off with this immense train of carriages; and such was its velocity, that in some parts the speed was frequently twelve miles an hour; and at that time the number of passengers was counted to be four hundred and fifty, which, together with the coals, merchandise, and carriages, would amount to near ninety tons. The engine,

with its load, arrived at Darlington, a distance of eight and three-quarter miles, in sixty-five minutes. The six wagons loaded with coals, intended for Darlington, were then left behind ; and, obtaining a fresh supply of water and arranging the procession to accommodate a band of music, and numerous passengers from Darlington, the engine set off again, and arrived at Stockton in three hours and seven minutes, including stoppages, the distance being nearly twelve miles." By the time the train reached Stockton there were about six hundred people riding in the cars or hanging on to them, and the train traveled on a steady average of four to six miles an hour from Darlington.

This road was primarily built to transport freight, and passengers were in reality an afterthought. But the directors decided to try a passenger coach, and accordingly Stephenson built one. It was an uncouth carriage, looking something like a caravan used at a country fair. The doors were at the ends, a row of seats ran along each side of the interior, and a long deal table extended down the centre. Stephenson called this coach the "Experiment," and in a short time it had become the most popular means of travel between Stockton and Darlington.

With the Stockton and Darlington Railway an assured and successful fact, the men who had been interested in building a line between Liverpool and Manchester earlier took up the subject again. Some improvement in the means of communication between the two cities was more needed than ever. The three canals and the turnpike road were often so crowded that traffic was

held up for days and even weeks. In addition the canal charges were excessive. On the other hand the railway builders had to meet the opposition of the powerful canal companies and landowners along the line they wished to open, and it took time and ingenuity to accomplish working adjustments.

The Liverpool and Manchester Railway bill came up for consideration in the House of Commons early in 1825. A determined stand was made against it, and the promoters and their engineers, chief among whom was Stephenson, had to be very modest in their claims. Stephenson had said to friends that he was confident that locomotives could be built that would carry a train of cars at the rate of twenty miles an hour, but such a claim would have been received by the public as ridiculous, and the engineer laughed to scorn. His opponents tried to badger him in every way they could, and ridicule even his modest statements. "Suppose now," said one of the members of Parliament in questioning him, "one of these engines to be going along a railroad at the rate of nine or ten miles an hour, and that a cow were to stray upon the line and get in the way of the engine; would not that be a very awkward circumstance?" "Yes," answered Stephenson, with a twinkling eye, "very awkward—*for the coo!*"

In fact very few of the members understood Stephenson's invention at all. A distinguished barrister represented about the general level of ignorance when he said in a speech, "Any gale of wind which would affect the traffic on the Mersey would render it *impossible* to set off a locomotive engine, either by poking the fire, or

keeping up the pressure of the steam till the boiler was ready to burst." Against such opposition it was not surprising that the bill failed of passage that year.

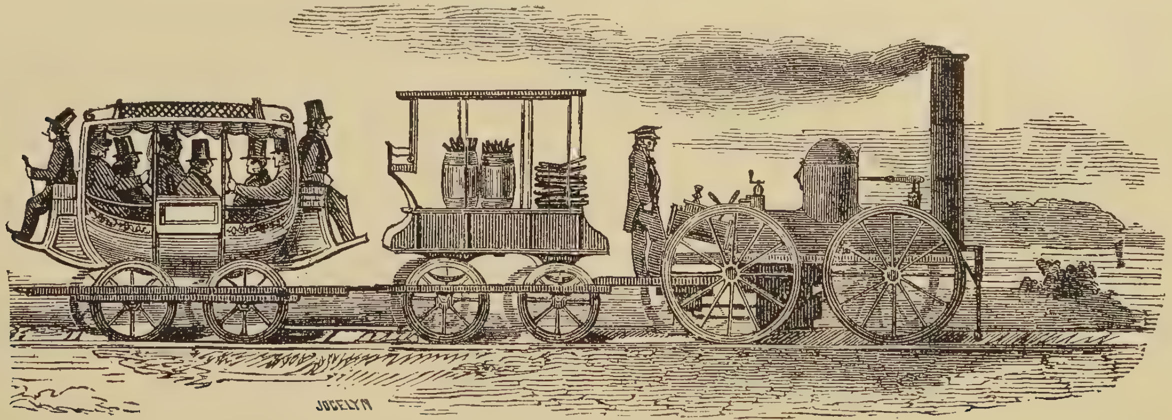
But the necessities of commerce could not be denied, and the following year the bill came up again, and was passed. Stephenson, as principal engineer of the railway, at once began its building. This in itself was a unique and very remarkable feat. An immense bog, called Chat Moss, had to be crossed, and Stephenson was the only one of the engineers concerned who did not doubt whether such a crossing were really possible. Ditches that were dug to drain the bog immediately filled up; as soon as one part was dug out the bog flowed in again; it swelled rapidly in rainy weather, and piles driven into it would sink down into the mire. But Stephenson finally built his road across it. A matting of heath and the branches of trees was laid on the bog's surface, and in some places hurdles interwoven with heather; this floating bed was covered over with a few inches of gravel, and on this the road proper was constructed. In addition to the crossing of Chat Moss a tunnel of a mile and a half had to be cut under part of Liverpool, and in several places hills had to be leveled or cut through. The old post-roads had never had to solve such problems, and George Stephenson deserves to rank as high as a pioneer of railroad construction as he does as builder of the working locomotive.

The directors of the railway were anxious to secure the best engine possible, and opened a general competition, naming certain conditions the engine must fulfil. Stephenson and Henry Booth built the "Rocket," and,

as this was the only engine that fulfilled all the conditions, took the prize. The "Rocket" was by far the most perfect locomotive yet built, having many new improvements that Stephenson had recently worked out.

The "Rocket" would make thirty miles an hour, a wonderful achievement, and was put to work drawing the gravel that was used in building the permanent road across Chat Moss. With the aid of such a powerful engine the work went on more rapidly, and in June, 1830, a trial trip was made from Liverpool to Manchester and back. There was a huge gathering at the stations at each end of the line. The train was made up of two carriages, filled with about forty passengers, and seven wagons loaded with stores. The "Rocket" drew this train from Liverpool to Manchester in two hours and one minute, and made the return trip in an hour and a half. It crossed Chat Moss at the rate of about twenty-seven miles an hour.

The public opening of the new road occurred on September 15, 1830. By that time Stephenson had built eight locomotives, and they were all ready for service. Much of the opposition of the general public had been overcome, and the opening was considered a great national event. The Duke of Wellington, then Prime Minister, Sir Robert Peel, and many other prominent men were present. George Stephenson drove the first engine, the "Northumbrian," and was followed by seven other locomotives and trains, carrying about 600 passengers. Stephenson's son drove the second engine, and his brother the third. They started from Liverpool, and the people massed along the line



One of the First Locomotives

cheered and cheered again as they saw the eight trains speed along at the rate of twenty-four miles an hour.

Unfortunately an accident occurred about seventeen miles out of Liverpool. The first engine, with the carriage containing the Duke of Wellington, had been stopped on a siding so that the Duke might review the other trains. Mr. Huskisson, one of the members of Parliament for Liverpool, and a warm friend and supporter of Stephenson and the railroad, had stepped from his coach, and was standing on the railway. The Duke called to him, and he crossed over to shake hands. As they grasped hands the bystanders began to cry, "Get in, get in!" Confused, Mr. Huskisson tried to go around the open door of the carriage, which projected over the opposite rail. As he did so he was hit by the "Rocket," an engine coming up on the other track, was knocked down, and had one leg crushed. That same night he died in the near-by parsonage of Eccles. This first serious railway accident, occurring at the very opening of the line, cast a gloom over the event. It revealed something of the danger coincident with the new invention. The Duke of Wellington and Sir Robert Peel both expressed a wish that the trains should return to Liverpool, but when it was pointed out that a great many people had gathered from all the neighboring country at Manchester, and that to abandon the opening would jeopardize the whole future success of the road, they agreed to go on. The journey was completed without any further mishap, and the people of Manchester gave the eight trains a warm welcome.

With the opening of this line the success of the railroad as a practical means of conveyance became assured. Singularly enough the builders of the railroad had based their estimates almost entirely on merchandise traffic, and had stated to the committee of the House of Commons that they did not expect their passenger coaches to be more than half filled. The carriages they planned to use would have carried 400 to 500 persons if full, but the road was hardly open before the company had to provide accommodations to carry 1,200 passengers daily, and the receipts from passenger travel immediately far exceeded the receipts from carrying freight.

Similarly the directors had expected that the average speed of the locomotives would be about nine or ten miles an hour, but very soon the trains were carrying passengers the entire thirty miles between Liverpool and Manchester in a little more than an hour. Travel by stage-coach had taken at least four hours, so that the railroad reduced the time nearly one-fourth. Engineers who came from a distance to examine the railroad were amazed at the smoothness of travel over it. Two experts from Edinburgh declared that traveling on it was smoother and easier than any they had known over the best turnpikes of Mr. Macadam. They said that even when the train was going at the very high speed of twenty-five miles an hour they "could observe the passengers, among whom were a good many ladies, talking to gentlemen with the utmost *sang froid*."

Business men were delighted at being able to leave Liverpool in the morning, travel to Manchester, do

business there, and return home the same afternoon. The price of coal, and the cost of carrying all classes of goods, was tremendously reduced. Another result, which was the opposite of what had been expected, was that the price of land along the line and near the stations at once rose. Instead of the noise and smoke of the trains frightening people away it seemed to charm them. The very landlords who had driven the surveyors off their property and done everything they could to hinder the builders now complained if the railroad did not pass directly through their domains, and begged for stations close at hand. Even the land about Chat Moss was bought up and improved, and all along the line what had been waste stretches began to blossom into towns and villages.

Stephenson continued to make improvements to his locomotives. He had already added the multitubular boiler, the idea of which was to increase the evaporative power of the boiler by adding to its heating surface by means of many small tubes filled with water. This increase of evaporative power increased the speed the engine could attain. In his new engine, the "Samson," he adopted the plan of coupling the fore and rear wheels of the engine. This more effectually secured the adhesion of the wheels to the rails, and allowed the carrying of heavier loads. He improved the springs of the carriages, and built buffers to prevent the bumping of the carriage ends, which had been very unpleasant for the earliest passengers. He also found a new method of lubricating his carriage axles, his spring frames, the buffers, and the brakes he had built for the trains.

The Liverpool and Manchester Railway was to be followed rapidly by other lines. George Stephenson was a good man of business as well as a good engineer. He suggested a number of lucrative opportunities to his Liverpool friends, and he took a financial share in some of them himself. He thought there should be a line between Swannington and Leicester, in order to increase the coal supply of the latter town, which was quite a manufacturing centre. A company was formed, and his son Robert was appointed engineer. In the course of the work Robert learned that an estate near the road was to be sold, and decided that there was considerable coal there. George Stephenson and two other friends bought the place, and he took up his residence there, at Alton Grange, in order to supervise the mining operations. The mine was very successful, and the railroad proved of the greatest value to the people of Leicester. Stephenson now changed his position from that of an employee of coal-owners to that of employer of many miners himself.

The first railroads to be built were principally branches of the Liverpool and Manchester one, and chiefly located in the mining and manufacturing county of Lancaster. But before long the great metropolis of London required railroad communication with the Midlands, and the London and Birmingham road was projected. Here again the promoters had to overcome gigantic obstacles, the opposition of the great landed proprietors who owned vast estates in the neighborhood of London, the opposition of the old posting companies, and of the conservative element who were afraid

of the great changes such a method of transportation would bring about. The natural difficulties of the first lines were increased a hundredfold, greater marshes had to be crossed, greater streams to be bridged, greater hills to be tunneled. But the greater the obstacles the greater Stephenson's resources proved. When some of his tunnels were flooded, because the workmen had cut into an unexpected bed of quicksand, he immediately designed and built a vast system of powerful pumps, and drew off enough water to fill the Thames from London Bridge to Woolwich, so that his workmen might continue the tunnels and line them with masonry sufficiently solid to withstand any future inrush of water.

The men who were back of this railroad would very probably never have projected it had they realized that the building of it would cost five million pounds. But when the road was opened for use the excess in traffic beyond the estimates was much greater than the excess in cost had been. The company was able to pay large dividends, and the builders found that they could have made no better investment. This London and Birmingham road, 112 miles long, was opened September 17, 1838. The receipts from passenger traffic alone for the first year were £608,564. Evidently travel by coach had not been as popular in reality as the conservatives had ardently maintained.

It is curious to note the many kinds of opposition these first railways encountered. Said Mr. Berkeley, a member of Parliament for Cheltenham, "Nothing is more distasteful to me than to hear the echo of our

hills reverberating with the noise of hissing railroad engines running through the heart of our hunting country, and destroying that noble sport to which I have been accustomed from my childhood." One Colonel Sibthorpe declared that he "would rather meet a highwayman, or see a burglar on his premises, than an engineer; he should be much more safe, and of the two classes he thought the former more respectable!" Sir Astley Cooper, the eminent surgeon, said to Robert Stephenson, when the latter called to see him about a new road, "Your scheme is preposterous in the extreme. It is of so extravagant a character as to be positively absurd. Then look at the recklessness of your proceedings! You are proposing to cut up our estates in all directions for the purpose of making an unnecessary road. Do you think for one moment of the destruction of property involved in it? Why, gentlemen, if this sort of thing is allowed to go on, you will in a very few years *destroy the noblesse!*" Physicians maintained that travel through tunnels would be most prejudicial to health. Dr. Lardner protested against passengers being compelled to put up with what he called "the destruction of the atmospheric air," and Sir Anthony Carlisle insisted that "tunnels would expose healthy people to colds, catarrhs, and consumption." Many critics expected the boilers of the locomotives to explode at any and all times. Others were sure that the railways would throw so many workmen out of employment that revolution must follow, and still others declared that England was being delivered ut-

terly into the power of a small group of manufacturers and mine-owners. But in spite of all this the people took to riding on the railways and England prospered.

The aristocracy held out the longest. Noblemen did not relish the thought of traveling in the same carriages with workmen. The private coach had for long been a badge of station. For a time, therefore, the old families and country gentility sent their servants and their luggage by train, but themselves jogged along the old post-roads in the family chariots. But there were more accidents and more delays in travel by coach than by train, and so, one by one, they pocketed their pride and capitulated. The Duke of Wellington, who had seen the accident to Mr. Huskisson near Liverpool, held out against such travel for a long time. But when Queen Victoria, in 1842, used the railway to go from London to Windsor, the last resistance ended, and the Iron Duke, together with the rest of his order, followed the Queen's example. Said the famous Dr. Arnold of Rugby, as he watched a train speeding through the country, "I rejoice to see it, and think that feudality is gone forever. It is so great a blessing to think that any one evil is really extinct."

Stephenson himself was one of the busiest men in the kingdom. He was engineer of half a dozen lines that were building, and he traveled incessantly. Many nights the only sleep he had was while sitting in his chaise riding over country roads. At dawn he would be at work, surveying, planning, directing, until nightfall. In three years he surveyed and directed the con-

struction of the North Midland line, running from Derby to Leeds, the York and North Midland, from Normanton to York, the Manchester and Leeds, the Birmingham and Derby, and the Sheffield and Rotherham. And in addition to this he traveled far and wide to give advice about distant lines, to the south of England, to Scotland, and to the north of Ireland to inspect the proposed Ulster Railway. He took an office in London, in order that he might take part in the railway discussions that were continually coming before Parliament. His knowledge of every detail relating to the subject was enormous. He knew both the engineering and the business sides most intimately. "In fact," he said to a committee of the House of Commons in 1841, "there is hardly a railway in England that I have not had to do with." Yet in spite of all this work he found time to look after his coal mines near Chesterfield, to establish lime-works at Ambergate, on the Midland Railway, and to superintend his flourishing locomotive factory at Newcastle.

King Leopold of Belgium invited him to Brussels, and there discussed with him his plans for a railway from Brussels to Ghent. The King made him a Knight of his Order of Leopold, and when the railway was finished George Stephenson was one of the chief guests of honor at the opening. Later he went to France, where he was consulted in regard to the new line that was building between Orleans and Tours. From there he went to Spain to look into the possible construction of a road between Madrid and the Bay of Biscay. He found the government of Spain

indifferent to the railway, and there were many doubts as to whether there would be sufficient traffic to pay the cost of construction. His report to the shareholders in this proposed "Royal North of Spain Railway" was therefore unfavorable, and the idea was shortly after abandoned.

Stephenson had moved his home from Alton Grange to Tapton House in 1838. The latter place was a large, comfortable dwelling, beautifully situated among woods about a mile to the northeast of Chesterfield. Here he lived the life of a country gentleman, free to indulge the strong love of nature that had always been one of his leading characteristics. He began to grow fine fruits and vegetables and flowers, and his farm and gardens and hothouses became celebrated all over England. He was continually sought out by inventors and scientific men, who wanted his views on their particular work. He also spent some time at Tapton in devising improvements for the locomotive. One of these was a three-cylinder locomotive, and such an engine was later used successfully on the North Eastern Railway. It was, however, found to be too expensive an engine for general railroad use. He also invented a new self-acting brake. He sent a model of this to the Institute of Mechanical Engineers at Birmingham, of which he was president, together with a report describing it in full. "Any effectual plan," he wrote, "for increasing the safety of railway traveling is, in my mind, of such vital importance, that I prefer laying my scheme open to the world to taking out a patent for it; and it will be a source of great pleasure to me to know that it has

been the means of saving even one human life from destruction, or that it has prevented one serious concussion."

He also gave great assistance to his son Robert, who was rapidly becoming a railway engineer second only to his father in fame. George Stephenson began the line from Chester to Holyhead, which was completed by Robert. Robert designed the tubular bridge across the Menai Straits on this line, which was considered a most remarkable feat. Permission could not be obtained to interfere with the navigation of the Straits in the slightest degree during the building, and so piers and arches could not be used. It occurred to Robert Stephenson that the train might be run through a hollow iron beam. Two tubes, which were to form the bridge, were made of wrought iron, floated out into the stream, and raised into position. This new and original railway bridge proved a success, and convinced England that Robert had inherited his father's genius for surmounting what seemed impossible natural difficulties. George Stephenson did not live to see this line completed. He died August 12, 1848.

In many respects Stephenson was like Watt. He came from the working classes, inheriting no special gift for science, and little leisure to follow his own bent. What he learned he got at first hand, in the coal mines and the engine shops. What he accomplished was due largely to indomitable perseverance. Others had built steam-engines that were almost successful as locomotives, but for one reason or another had never pushed their invention to that point where the world could actually

use it. When Stephenson had built his locomotive he fought for it, he made men take an interest in it, and the world accept it. He always spoke of his career as a battle. "I have fought," said he, "for the locomotive single-handed for nearly twenty years, having no engineer to help me until I had reared engineers under my own care." And again he said, "I put up with every rebuff, *determined* not to be put down."

Stephenson did for the locomotive what Watt did for the condensing engine. He took the primitive devices of other men, and by the rare powers of selection, combination, and invention produced a finished product of wonderful power and efficiency. True it is that neither Watt nor Stephenson were the first men to conceive of a steam-engine or a locomotive, nor even the first to build working models, but they were the first to finish what they began, and add the steam-engine and the locomotive to the other servants of men.

Dr. Arnold was doubtless right when he looked upon the railway as presaging the end of the feudal system. Its value is beyond any estimate. It has widened man's horizon, and given him all the lands instead of only the limits of his homestead.

X

MORSE AND THE TELEGRAPH
1791–1872

ON the packet ship *Sully*, sailing from the French port of Havre for New York on October 1, 1832, were Dr. Charles T. Jackson, of Boston, who had been attending certain lectures on electricity in Paris, and an American artist named Samuel Finley Breese Morse. Dr. Jackson was intensely interested in electricity, and more especially in some experiments that Faraday had lately been making in regard to it. He had an electro-magnet in his trunk, and one day, as a number of the passengers sat at dinner, he began to describe the laws of electro-magnetism as they were then known. He told how the force of a magnet could be tremendously increased by passing an electric current a number of times about a bar of soft iron. One of the diners asked how far electricity could be transmitted and how fast it traveled. Dr. Jackson answered that it seemed to travel instantaneously, none of the experimenters having detected any appreciable difference in time between the completing of the electric circuit and the appearance of the spark at any distance. Morse, who had been interested in the study of electricity at Yale College, said that if the electric current could be made visible in any part of the circuit he saw no reason why messages

could not be sent instantaneously by electricity. To send a message would simply require the breaking of the circuit in such different ways as could be made to represent the letters of the alphabet. The conversation went on to other subjects, but the artist kept the conclusion he had just stated in mind. That night he walked the deck discussing the matter with Dr. Jackson, and for the rest of the voyage he was busy jotting down suggestions in his note-book and elaborating a plan for transforming breaks in an electric current into letters.

The facts at his disposal, and his first method of dealing with them, were comparatively simple. The electric current would travel to any distance along a wire. The current being broken, a spark would appear. The spark would stand for one letter. The lack of a spark might stand for another. The length of its absence would indicate another. With these three indications as a starting-point he could build up an alphabet. As there was no limit to the distance that electricity would travel there seemed no reason why these dots and dashes, or sparks and spaces, should not be sent all around the world.

Professor Jeremiah Day had taught Morse at Yale that the electric spark might be made to pierce a band of unrolling paper. Harrison Gray Dyar, of New York, in 1827, had shown that the spark would decompose a chemical solution and so leave a stain as a mark, and it was known that it would excite an electro-magnet, which would move a piece of soft iron, and that if a pencil were attached to this a mark would be made on

paper. Therefore Morse knew that if he devised his alphabet he had only to choose the best method of indicating the dots and dashes by the current. The voyage from Havre to New York occupied six weeks, and during the greater part of this time he was busy working out a mechanical sender which would serve to break the electric current by a series of types set on a stick which should travel at an even rate of speed. The teeth of the type would complete the circuit or would break the current as they passed, and so send the letters. At the receiving end of the line the current as it was sent would excite the electro-magnet, which would be attached to a pencil, and so make a mark, and each mark would represent one of the symbols that were to stand for letters. He worked day and night over these first plans, and after a few days showed his notes to Mr. William C. Rives, a passenger, who had been the United States Minister to France. Mr. Rives made various criticisms, and Morse took these up in turn, and after long study overcame each one, so that by the end of the voyage he felt that he had worked out a practical method of making the electric current send and receive messages.

At a later date a contest arose as to the respective claims of Samuel Morse and Dr. Jackson to be considered the inventor of the recording telegraph, and the evidence of their fellow passengers on board the *Sully* was given in great detail. From all that was then said it would appear that Dr. Jackson knew quite as much, if not more, about the properties of electromagnetism than Morse did, but that he was of a

speculative turn of mind, whereas Morse was practical, and capable of reducing the other's theories to a working basis. The note-books he submitted, and which were well remembered by many of his fellow voyagers, showed the various combinations of dots, lines, and spaces with which he was constructing an alphabet, and also the crude diagrams of the recording instrument which should mark the dots and lines on a rolling piece of paper. Captain Pell, in command of the *Sully*, testified later, that as the packet came into port Morse said to him, "Well, Captain, should you hear of the telegraph one of these days as the wonder of the world, remember that the discovery was made on board the good ship *Sully*." The times were ripe for his great invention, and although other men, abler scientists and students, had foreseen the possibilities of such a system, it was Morse who determined to put it into practice.

But Samuel Morse was a painter, and all his career thus far had lain along artistic lines. True, when he was an undergraduate at Yale he had been much interested in Professor Day's lectures on electricity, and had written long letters home in regard to them. But when he was about to graduate, he wrote to his father, a well-known clergyman of Charlestown, Massachusetts, "I am now released from college, and am attending to painting. As to my choice of a profession, I still think I was made for a painter, and would be obliged to you to make such arrangements with Mr. Allston for my studying with him as you shall think expedient. I should desire to study with him during the winter; and, as he expects to return to England in the spring, I

should admire to be able to go with him. But of this we will talk when we meet at home."

Washington Allston was at that time the leading influence in the primitive art life of the country, and Morse was very fortunate to have won his friendship and interest. Allston took him to England, and there introduced him to Benjamin West, the dean of painters and a man who was always eager to aid young countrymen of his who planned to follow his career. Morse made a careful drawing of the Farnese Hercules and took it to West. The veteran examined it and handed it back, saying, "Now finish it." Morse worked over it some time longer, and returned it to West. "Very well, indeed, sir," said West. "Go on and finish it." "Is it not finished?" asked Morse. "See," said West, "you have not marked that muscle, nor the articulation of the finger-joints." Again Morse worked over it, and again returned, only to meet with the same counsel to complete the picture. Then the older man relented. "Well, I have tried you long enough," said he. "Now, sir, you have learned more by this drawing than you would have accomplished in double the time by a dozen half-finished beginnings. It is not many drawings, but the character of one which makes a thorough draughtsman. Finish one picture, sir, and you are a painter."

Morse now decided to paint a large picture of "The Dying Hercules" for exhibition at the Royal Academy. In order to be sure of the anatomy he first modeled the figure in clay, and this cast was so well done that, acting on West's advice, he entered it for a prize in

sculpture then offered by the Society of Arts. This entry won, and the young American was presented with the gold medal of the society before a distinguished audience. The picture that he painted from this model was hung at the exhibition of the Royal Academy, and received high praise from the critics, so that Morse felt he had begun his career as artist most auspiciously.

His natural inclination was toward the painting of large canvases dealing with historical and mythical subjects, which were much in fashion at that period, and he now set to work on the subject, "The Judgment of Jupiter in the case of Apollo, Marpessa, and Idas." This was to be submitted for the prize of fifty guineas and medal offered by the Royal Academy. It seems to have been a fine piece of work, and met with West's hearty praise, but before it could be submitted the artist was obliged to return home at an urgent summons from his father.

Boston had already heard of Morse's success in London when he reached home in October, 1815. His "Judgment of Jupiter" was exhibited, and became the talk of the town, but when he opened a studio and began to paint no one offered to buy any of his pictures. He needed money badly, and he saw none coming his way. After a year's struggle he closed his studio, and traveled through the country sections of New England, looking for work as a portrait painter. This he found, and he wrote to his parents from Concord, New Hampshire, "I have painted five portraits at $15 each, and have two more engaged and many talked of. I think

I shall get along well. I believe I could make an independent fortune in a few years if I devoted myself exclusively to portraits, so great is the desire for good portraits in the different country towns."

In Concord he met Miss Lucretia P. Walker, whom he married a few years later. Meantime he went to visit his uncle in Charleston, South Carolina, and found his portraits so popular that he received one hundred and fifty orders in a few weeks. He was also commissioned to paint a portrait of James Monroe, then President, for the Charleston Common Council, and the picture was considered a striking masterpiece. He soon after married, and settled his household goods in New York, with $3,000 made by his portraits, as his capital.

He knew what he wanted to do, to paint great historical pictures. But the public did not appreciate his efforts in that line. He painted a large exhibition picture for the National House of Representatives, but it was not purchased by the government. On the other hand the Corporation of New York commissioned him to paint the portrait of Lafayette, who was then visiting America. At the same time he became enthusiastic over the founding of a new society of artists, and was chosen the first president of the National Academy of Design.

His small capital was dwindling. His efforts to paint historical pictures rather than portraits, and his share in paying off certain debts of his father's, had made great inroads on the money he had saved. To add to his misfortunes his wife died in February, 1825. In 1829

he went abroad, visited the great galleries of Europe, and tried to find a more ready market for his historical studies. It was on his return from France in 1832 that the conversation of Dr. Jackson and the other passengers turned his thoughts in the direction of an electric telegraph.

Now came his gradual transformation from painter to inventor. His brothers gave him a room with them in New York, and this became his studio and laboratory at one and the same time. Easels and plaster-casts were mixed with type-moulds and galvanic batteries, and Morse turned from a portrait to his working model of telegraph transmitter and back again a dozen times a day. He painted to make his living, but his interest was steadily turning to his invention.

He had many friends, and a wide reputation as a man of great intellectual ability, and in a few years he was appointed the first Professor of the Literature of the Arts of Design in the new University of the City of New York. This gave him a home in the university building on Washington Square, and there he moved his apparatus. At this time he was chiefly concerned with the question of how far a message could be sent by the electric current, for it was known that the current grew feebler in proportion to the resistance of the wire through which it travels. He had learned that the electro-magnet at the receiving end would at any great distance become so enfeebled that it would fail to make any record of the message. His solution of this difficulty was a relay system. He explained this to Professor Gale, a colleague at the university, who

later testified as to Morse's work. "Suppose," said the inventor, "that in experimenting on twenty miles of wire we should find that the power of magnetism is so feeble that it will not move a lever with certainty a hair's breadth: that would be insufficient, it may be, to write or print; yet it would be sufficient to close and break another or a second circuit twenty miles farther, and this second circuit could be made, in the same manner, to break and close a third circuit twenty miles farther, and so on around the globe." Gale proved of great assistance. So far Morse had only used his recorder over a few yards of wire, his electro-magnet had been of the simplest make, and his battery was a single pair of plates. Gale suggested that his simple electro-magnet, with its few turns of thick wire, should be replaced by one with a coil of long thin wire. In this way a much feebler current would be able to excite the magnet, and the recorder would mark at a much greater distance. He also urged the use of a much more powerful battery. The two men now erected a working telegraph in the rooms of the university, and found that they could send and receive messages at will.

It is interesting to read Morse's own words in regard to the beginning of his work at Washington Square. "There," he said, "I immediately commenced, with very limited means, to experiment upon my invention. My first instrument was made up of an old picture or canvas frame fastened to a table; the wheels of an old wooden clock, moved by a weight to carry the paper forward; three wooden drums, upon one of which the

paper was wound and passed over the other two; a wooden pendulum suspended to the top piece of the picture or stretching frame and vibrating across the paper as it passed over the centre wooden drum; a pencil at the lower end of the pendulum, in contact with the paper; an electro-magnet fastened to a shelf across the picture or stretching frame, opposite to an armature made fast to the pendulum; a type rule and type for breaking the circuit, resting on an endless band, composed of carpet-binding, which passed over two wooden rollers moved by a wooden crank.

"Up to the autumn of 1837 my telegraphic apparatus existed in so rude a form that I felt a reluctance to have it seen. My means were very limited—so limited as to preclude the possibility of constructing an apparatus of such mechanical finish as to warrant my success in venturing upon its public exhibition. I had no wish to expose to ridicule the representative of so many hours of laborious thought. Prior to the summer of 1837, at which time Mr. Alfred Vail's attention became attracted to my telegraph, I depended upon my pencil for subsistence. Indeed, so straightened were my circumstances that, in order to save time to carry out my invention and to economize my scanty means, I had for many months lodged and eaten in my studio, procuring my food in small quantities from some grocery and preparing it myself. To conceal from my friends the stinted manner in which I lived, I was in the habit of bringing my food to my room in the evenings, and this was my mode of life for many years."

Before he devoted all his time to his invention Morse

had been anxious to paint a large historical picture for one of the panels in the rotunda of the Capitol at Washington. His offer had been rejected, and this had led a number of his friends to raise a fund and commission him to paint such a picture. He chose as his subject "The Signing of the First Compact on Board the *Mayflower*." But he was now so much engrossed with his experiments that he gave up the plan and the fund was returned to the subscribers.

We have already heard in Morse's statement of the arrival of Mr. Alfred Vail. He was to have much to do with the success of Morse's invention. He had happened to call at the university building when the inventor was showing his models to several visiting scientists. "Professor Morse," said Mr. Vail, "was exhibiting to these gentlemen an apparatus which he called his Electro-Magnetic Telegraph. There were wires suspended in the room running from one end of it to the other, and returning many times, making a length of several hundred feet. The two ends of the wire were connected with an electro-magnet fastened to a vertical wooden frame. In front of the magnet was its armature, and also a wooden lever or arm fitted at its extremity to hold a lead pencil. . . . I saw this instrument work, and became thoroughly acquainted with the principle of its operation, and, I may say, struck with the rude machine, containing, as I believed, the germ of what was destined to produce great changes in the conditions and relations of mankind. I well recollect the impression which was then made upon my mind. . . . Before leaving the room in which

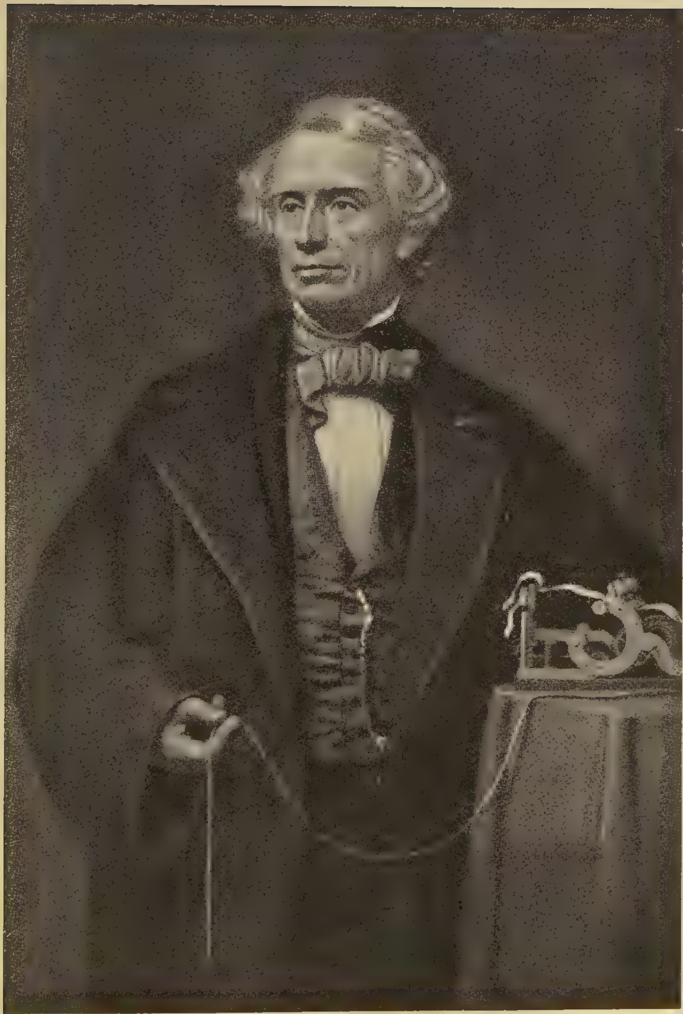
I beheld for the first time this magnificent invention, I asked Professor Morse if he intended to make an experiment on a more extended line of conductors. He replied that he did, but that he desired pecuniary assistance to carry out his plans. I promised him assistance provided he would admit me into a share of the invention, to which proposition he assented. . . . The question then arose in my mind, whether the electro-magnet could be made to work through the necessary lengths of line, and after much reflection I came to the conclusion that, provided the magnet would work even at a distance of eight or ten miles, there could be no risk in embarking in the enterprise. And upon this I decided in my own mind to sink or swim with it."

Alfred Vail secured his father's financial assistance, and in September, 1837, an agreement was executed by which Vail was to construct a model of Morse's telegraph for exhibition to Congress, and to secure the necessary United States patents, in return for which he was to have a one-fourth interest in these patent rights. The patent was obtained on October 3, 1837, and Vail set to work to prepare the new models. Almost all the apparatus that was used had to be specially made for the purpose, or altered from its original use. The first working battery was placed in a cherry-wood box divided into cells and lined with beeswax, and the insulated wire was the same as that the milliners used in building up the high bonnets fashionable at that day. Vail made certain improvements as he worked on his model. He replaced the recording pencil with a fountain pen, and

instead of the zigzag signals used the short and long lines that came to be called "dots" and "dashes." He learned from the typesetters of a newpaper office what letters occurred most frequently in ordinary usage, and constructed the Morse or Vail code on the principle of using the simplest signals to represent those letters that would be most needed.

By the winter of 1837 many people had seen the telegraph instruments at the university building, but few of them considered them more than ingenious toys. Scientific men had talked of the possibilities of an electric telegraph for a number of years, but the public had seen none actually installed. Even Vail's father began to doubt the wisdom of his son's investment. To convince him the young man, on January 6, 1838, asked his father to come to the experimenting shop where Morse and he were working. He explained how the model operated, and said that he could send any message to Morse, who was stationed some distance away at the receiving end. The father took a piece of paper, and wrote on it, "A patient waiter is no loser." "There," said he, "if you can send this, and Mr. Morse can read it at the other end I shall be convinced." The message was sent over the wire, and correctly read by Morse. Then Mr. Vail admitted that he was satisfied.

Morse now decided to bring his invention to the attention of Congress. He was permitted to set up his apparatus in the room of the House Committee on Commerce at the Capitol. There he gave an exhibition to the committee, but most of them doubted if his plans for sending long-distance messages were really



Morse and the First Telegraph

feasible. On February 21, 1838, he worked his telegraph through ten miles of wire contained on a reel, with President Van Buren and his cabinet as an audience. Then he asked that Congress appropriate sufficient money to enable him to construct a telegraph line between Washington and Baltimore. The chairman of the Committee on Commerce, Francis O. J. Smith, of Maine, was very much interested by now, and drafted a bill appropriating $30,000 for this purpose. But the bill did not come to a vote, and the matter was allowed to drop.

Meantime rival claimants to the invention were appearing on all sides. Morse decided that he must try to secure European patents, and went abroad for that purpose. His claim was opposed in England, and in France it was finally decided that in the case of such an invention the government must be the owner. He was well received, and given the fullest credit for his achievements, but the patents were refused, and he had to return home with his small capital much depleted and business prospects at a low ebb. Moreover, the United States government now seemed to have lost interest in the subject, and his partners, the Vails, were having financial difficulties of their own.

While he waited he continued to experiment. He believed that the electric current could be sent under water as easily as through the air, and to try this he insulated a wire two miles long with hempen threads that were saturated with pitch-tar and wrapped with India-rubber. He unreeled this cable from a small row-boat between Castle Garden and Governor's Island in

New York Harbor on the night of October 18, 1842. At daybreak Morse was at the station at the Battery, and began to send a message through his submarine cable. He had succeeded in sending three or four characters when the communication suddenly stopped, and although he waited and kept on with his trials no further letters could be transmitted. On investigation it appeared that no less than seven ships were lying along the line of Morse's cable, and that one of these, in getting under way, had lifted the cable on her anchor. The sailors hauled two hundred feet of it on deck, and, seeing no end to it, cut it, and carried part of it away with them. But the test had proved Morse's theory, and he became convinced that in time messages could be sent across the ocean as easily as over land.

When Congress met in December, 1842, Morse again appeared in Washington to obtain financial help. Congress was not very enthusiastic over his project, but the House Committee on Commerce finally recommended an appropriation of $30,000, and a bill to that effect was passed in the House of Representatives by the small majority of six votes. The Senate was overcrowded with bills, and Morse's was continually postponed. In the early evening of the last day of the session there were one hundred and nineteen bills to come to vote before his, and it seemed impossible that it should be taken up. Morse, who had been sitting in the gallery all day, concluded that further waiting was useless, and went back to his hotel, planning to leave for New York early the next morning. He found that after paying his hotel bill he would have less than half

a dollar in the world. But as he came down to breakfast the following morning he was met by Miss Ellsworth, the daughter of his friend, the Commissioner of Patents. She held out her hand, saying, "I have come to congratulate you."

"Congratulate me! Upon what?" asked Morse.

"On the passage of your bill," she answered.

"Impossible! It couldn't come up last evening. You must be mistaken," said the inventor.

"No," said Miss Ellsworth, "father sent me to tell you that your bill was passed. He remained until the session closed, and yours was the last bill but one acted upon, and it was passed just five minutes before the adjournment."

In return for this news Morse promised that Miss Ellsworth should send the first message when his telegraph line was opened. That same day he wrote to Alfred Vail that the bill "was reached a few minutes before midnight and passed. This was the turning point in the history of the telegraph. My personal funds were reduced to the fraction of a dollar, and, had the passage of the bill failed from any cause, there would have been little prospect of another attempt on my part to introduce to the world my new invention."

It had been decided to construct an underground line between Washington and Baltimore, the conductor being a five-wire cable laid in pipes, but after several miles had been laid from Baltimore the insulation broke down. A very large part of the government grant had been spent, and the situation looked very dubious. But after some discussion it was determined to carry

the wire by poles, as this could be done much more rapidly and at smaller expense.

The National Whig Convention, to nominate candidates for President and Vice-President, met at Baltimore on May 1, 1844. The overhead wire had been started from Washington toward Baltimore, and by that day twenty-two miles of it were in working order. The day before the convention met Morse had arranged with Vail that certain signals should mean that certain candidates had been nominated. Henry Clay was named for President, and the news was carried by railroad to the point where Morse had stretched his wire. He signaled it to Washington, and the Capitol heard it long before the first messages arrived by train.

On May 24, 1844, the line was completed, and Miss Ellsworth was invited to send the first message from the room of the United States Supreme Court to Baltimore. She chose the Biblical words "What hath God wrought?" and this was sent over the telegraph. Vail received the message in Baltimore, and the first demonstration was a complete success. The younger man had added an improvement of his own; instead of the dots and dashes being indicated by the markings of a pen or pencil they were embossed on the paper with a metal stylus.

An incident in connection with the Democratic Convention, which was then in session in Baltimore for the purpose of nominating presidential candidates, added to the public interest in Morse's telegraph. The Democrats had named James K. Polk for President and Silas Wright for Vice-President. The news was sent by

wire to Washington, and Mr. Wright sent his message declining the honor over the telegraph. The chairman of the meeting, Hendrick B. Wright, received the message. In a letter to Benson J. Lossing he says, "As the presiding officer of the body I read the despatch, but so incredulous were the members as to the authority of the evidence before them that the convention adjourned over to the following day to await the report of the committee sent over to Washington to get *reliable* information on the subject." The committee returned with word that the telegraph message had been correct. Then, all but the convention committee being excluded from the telegraph room in Baltimore, message after message was sent over the wire by Vail to Morse and Silas Wright in Washington. The committee used many arguments to urge Wright's acceptance; he answered them all, persisting in his refusal; and finally this decision was reported to the convention, which nominated Mr. Dallas in his place. The story of the part the new invention had played quickly spread abroad, and added to the intense public interest now focussed on it.

On April 1, 1845, the first telegraph line between Washington and Baltimore was opened for general use. Congress had appropriated $8,000 to maintain it for the first year, and placed it under the direction of the Postmaster-General. The official charge was one cent for every four characters transmitted. The receipts of the first four days were one cent, for the fifth day twelve and a half cents, for the seventh sixty cents, for the eighth one dollar and thirty-two cents, for the

ninth one dollar and four cents. Morse offered to sell his invention to the government for $100,000, but the Postmaster-General declined the offer, stating in his report that the service "had not satisfied him that under any rate of postage that could be adopted its revenues could be made equal to its expenditures."

With the public opening of the line between Washington and Baltimore the practical success of the new electric telegraph was assured. The Magnetic Telegraph Company was formed to carry a wire from New York to Philadelphia, and thence another line was run to Baltimore in 1846. The telegraph being an accomplished fact, pirates of the patent now appeared, and for a course of years Morse and his partners had to fight for their rights. Henry O'Reilly, who had been employed in building the first lines, contracted to construct another from Philadelphia to St. Louis, and when that was finished he formed a company known as the People's Line, to run to New Orleans. He claimed to use instruments entirely different from those patented by Morse, and so to be free from the payment of royalties. Morse applied for an injunction, and on appeal the Federal Supreme Court decided in his favor. Other similar suits followed, and in each one the decision justified Morse's contention. The conclusion was that even though other men had known of the possibilities by experiment, it was the fact that he had first put the matter into practical form directed toward a specific purpose, and hence was to be regarded in law as the inventor.

The telegraph grew with the country. The Western

Union Company followed the stage-coach across the plains to California, and soon the frontier towns were linked to the large cities of the East. Other men took up the work in other lines, and in 1854 Cyrus W. Field formed the Atlantic Telegraph Company to lay a cable between America and Europe. As Morse had said when he first began seriously to study the subject on board the *Sully*, "If it will go ten miles without stopping I can make it go around the globe."

The inventor found himself universally honored, and at last a very wealthy man. He married Miss Griswold of Poughkeepsie, and bought an estate of two hundred acres near that city. He was given degrees by American and European universities and societies, was made a member of the French Legion of Honor, received orders of knighthood from the rulers of Spain and Italy, Denmark, Turkey, and Portugal. In 1858 the Emperor of the French called a Congress in Paris to honor Morse, and the Congress awarded him a gift of 400,000 francs as a token of gratitude. In his eightieth year his statue in bronze was placed in Central Park, New York, and his countrymen did their utmost to show him their appreciation of his great achievement. He died in 1872, a short time after he had unveiled a statue of Benjamin Franklin in New York's Printing-house Square.

Morse was the inventor, but his partner Alfred Vail had a great share in making the present telegraph. He discarded the original porte-rule and type of the transmitter for the key or lever, moved up and down by hand to complete or break the circuit. He perfected

the dot and dash code, he invented the device for embossing the message, and replaced the inking pen by a metal disc, smeared with ink, that rolled the dots and dashes on the paper. When it was found that the telegraph operators would read the signals from the clicking of the marking lever instead of from the paper, he made an instrument which had no marking device, and in which the signals were sounded by the striking of the lever of the armature against the metal stops. This "sounder" soon drove out the old Morse recorder. The present instrument is in its mechanical form far more the work of Vail than of Morse.

XI

McCORMICK AND THE REAPER
1809–1884

THE same sturdy pioneer stock that gave America Daniel Boone and Lincoln, Robert Fulton and Andrew Jackson, produced the inventor of the reaper. He came of a line of resourceful, fearless Scotch-Irish settlers, bone of the bone and sinew of the sinew of those generations that laid the broad foundations of the United States. His great-grandfather had been an Indian fighter in the colony of Pennsylvania, his grandfather had moved to Virginia and fought in the Revolution, and his father had built a log-house and tilled a farm in that strip of arable Virginia land that lay between the Blue Ridge and the Alleghany Mountains. He prospered, and added neighboring farms to his original holding ; he had two grist-mills, two sawmills, a blacksmith shop, a smelting-furnace, and a distillery ; he invented new makes of farm machinery, and in addition was a man of considerable reading, able to hold his own in discussion with the lawyers and the clergymen of the countryside. He was of that same well-developed type of countryman of whom so many were to be found in the thirteen original states and the borderlands to the west, that settler type which was the real backbone of the young country.

The McCormick house and farm was almost a small village in itself. There were eight children, and their shoes were cobbled, their clothes woven, their very beds and chairs and tables built at home. Whatever was needed could be done, the family were always busy within doors or without, and the spirit of helpfulness and invention was in the air. Into such a setting Cyrus Hall McCormick was born in 1809, the same year that saw the birth of Lincoln.

He went to one of the Old Field Schools, so called because it was built on ground that had been abandoned for farm use. He learned what other boys and girls were learning in simple country schools, but he studied harder than most of them, because he had a keen desire to understand thoroughly whatever subject he started. He saw his father busy in his workshop at all spare moments, and he took him as a pattern. After weeks of work he brought his teacher a remarkably exact map of the world, drawn to scale, and outlined in ink on paper pasted on linen, and fastened on two rollers. The work showed his ingenious fancy, and perhaps determined his father to have him educated as a surveyor. At eighteen he began this study, and had soon won a good reputation in the neighborhood as an engineer. Much of the time he spent in the fields with his father, and here he soon learned that reaping wheat was no easy task, and that swinging a wheat cradle under the summer sun was hard on both the temper and the back.

Many men had tried to lighten the farmer's labor in cutting grain, and Cyrus McCormick's father had long

had the ambition to invent a reaper. He had succeeded in building a cumbersome machine that was pushed at the back by a pair of horses. The plan of the machine was well enough ; it consisted of a row of short curved sickles that were fastened to upright posts. Revolving rods drove the wheat up against the sickles. The machine acted properly, but the grain would not. Instead of standing up straight and separated to be cut the wheat would more often come in great bunches, twisting about the sickles and getting tangled in the machinery. Mr. McCormick tried the machine in the harvesting of 1816, but it would not work, and had to be carted away to the workshop as an invention gone wrong. But he persevered with this idea, and from time to time built other models. After a number of years he brought forth a machine that would cut, but left the wheat after cutting in a badly tangled shape. He saw that this was not sufficient. The reaper to be of real use must dispose of the grain properly as well as shear the stalks.

Cyrus now took up the work that his father reluctantly abandoned. He decided to build his reaper on entirely new lines. First he dealt with the problem of how to separate the grain that was to be cut from that which was to be left standing. This he finally solved by adding a curved arm, or divider, to the end of his reaper's blade. In this way the grain that was to be cut would be properly fed to the knife.

But the grain was apt to be badly tangled before the reaper reached it, and his machine must be able to cut that which was pressed down and out of shape as

well as that which was standing straight. To accomplish this he decided that his knife must have two motions, one a forward cut, and the other sideways. He tried many plans before he finally hit upon one that solved this for him. It was a straight knife blade that moved forward and backward, cutting with each motion. This idea became known as the reciprocating blade.

Yet even though the machine could divide the grain properly, and the knife cut with a double motion, there was the possibility that the blade might simply press the grain down and so slide over it. This was especially apt to be the case after a rain, or when the grain had been badly blown about by the wind. The problem now was how to hold it upright. He found the solution lay in adding a row of indentations that projected a few inches from the edge of the knife, and acted like fingers in catching the stalks and holding them in place to be cut.

These three ideas, the divider, the reciprocating blade, and the fingers, were all fundamental devices of the machine Cyrus McCormick was building. They all met the question of how the grain could be cut. To these he next added a revolving reel, that would lift any grain that had fallen and straighten it, and a platform to catch the grain as it was cut and fell. His idea was that a man should walk along beside the reaper and rake off the grain as it fell upon the platform.

Two more devices, and his first machine was completed. One was to have the shafts placed on the out-

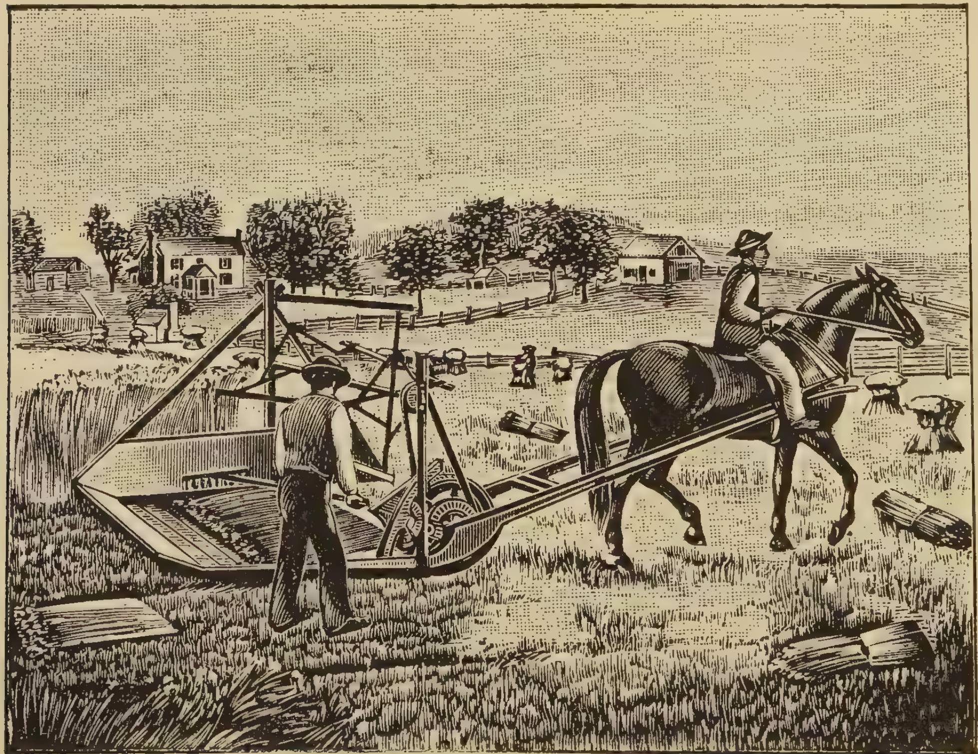
side of the reaper, or so that the horse would pull it sideways, instead of having to push it, as had been the case with his father's model. The other was to have the whole machine practically operated by one big wheel, which should bear the weight and move the knife and the reel.

It had taken young McCormick many months to work out all these problems, and there were only one or two weeks each year, the harvest weeks, when he could actually try his machine. He wanted to use it in the spring of 1831, but he found that the work of finishing all the necessary details was enormous. He begged his father to leave a small patch of wheat for him to try to cut, and at last, one day in July of that year, he drove his cumbersome machine into the field. All his family watched as the reaper headed toward the grain. They saw the wheat gathered and swept down upon the knife, they saw the blade move back and forth and cut the grain, and then saw it fall upon the little platform. The machine worked with hitches, not nearly so smoothly nor so efficiently as it should, but it did work; it gathered the grain in and it left it in good shape to be raked off the platform. The trial proved that such a machine could be made to do the work, and that was all that the inventor wanted.

He drove it back to his workshop and made certain changes in the reel and the divider. Then, several days later, he drove it over to the little settlement at Steele's Tavern, and cut six acres of oats in one afternoon. That was a marvelous feat, and caused great wonder in the countryside, but the harvesting season

had ended, and the inventor would have to wait a year before he could prove the use of his machine again.

By the next year McCormick was ready for a larger audience. The town of Lexington lay some eighteen miles south of his home, and he made arrangements with a farmer there, named John Ruff, to give an exhibition of his reaper in the latter's field. Over a hundred people were present when McCormick arrived, all curious to see what could be done with the complicated-looking machine. Many of them were harvesters themselves, and none too eager to see a mechanical device enter into competition for their work. The field was hilly and rough, and the reaper careened about in it like a ship in a gale. The farmer grew indignant, and protested that McCormick would ruin all his wheat, and the laborers began to jeer and joke at the machine's expense. The exhibition gave every sign of proving a failure when one of the spectators called out that he owned the next field and would be glad to give McCormick a chance there. This field was level, and the young man quickly turned his reaper into it. Before sunset he had cut six acres of wheat, and convinced his audience that his machine was a great improvement over the old method. That evening he drove the reaper to the court-house square and explained its working to the towns people. Very few of them saw how it was to revolutionize the farmer's labor, but one or two did. Professor Bradshaw, of the local academy, studied the machine, and then stated publicly that in his opinion, "This machine is worth a hundred thousand dollars."



THE EARLIEST REAPER

But if Cyrus McCormick had been fortunate in growing up on a farm where he could study the problem of cutting grain at first hand he was now to find that he was not so fortunate when it came to building other reapers and marketing them. His home was four days' travel from Richmond. He must have money to get the iron for his machines, to advertise, and to pay agents to try to sell them. He had very little money. He did advertise in the *Lexington Union* in September, 1833, offering reapers for sale at fifty dollars; but there were no answers to his advertisements. So skeptical were the farmers that it was seven years before one bought a reaper of him. But he had faith enough in his invention to take out a patent on it in 1834.

Until now McCormick had depended on the farm for his livelihood, but there was little profit in this, and he turned his attention to a deposit of iron ore in the neighborhood, and built a furnace and began to make iron. This succeeded until the panic of 1837 reached the Virginia country and brought debt and lowered prices with it. Cyrus surrendered his farm and what other property he had to his creditors. None of them was sufficiently interested in the crude reaper to consider it worth taking.

But the inventor hung on to his faith in this machine, although no one appeared to buy it, and the expense he had gone to in making it had practically bankrupted him. And his faith met with its reward, for one day in 1840 a stranger rode up to the door of his workshop and offered fifty dollars for a reaper. He had seen one of the machines on exhibition, and had decided to try

it. A little later two other farmers who lived on the James River appeared and gave McCormick two more orders. He had the satisfaction of knowing that in the harvest of 1840 three of his reapers were having a trying out.

The next year he was busy trying to perfect a blade that would cut wet grain. This took him weeks of experimenting, but at last he found that a serrated edge of a certain pattern would produce the effect he wanted. He added this to the new machines he was building, fixed the price of the reaper at one hundred dollars, and in 1842 sold seven machines, in 1843 twenty-nine, and in 1844 fifty. At last he had justified himself, and the log workshop had become a busy factory.

An invention of such great value to the farmer naturally advertised itself through the country districts. Men who heard of a machine that would cut one hundred and seventy-five acres of wheat in less than eight days—as happened in one case—naturally decided that it was worth investigating. And those who already owned machines saw a chance to make money by selling to their neighbors. One man paid McCormick $1,333 for the reaper agency of eight counties, another $500 for the right in five other counties, and a business man offered $2,500 for the agency in southern Virginia. Meantime orders were coming in from the distant states of Illinois, Wisconsin, Missouri, and Iowa, and the little home factory was being pushed to the utmost.

But it was not only difficult to obtain the necessary

materials for building reapers on the remote Virginia farm, it was almost impossible to ship the machines ordered in time for the harvests. Those that went west had to be taken by wagon to Scottsville, sent down the canal to Richmond, put on shipboard for the long journey down the James River to the Atlantic and so by ocean to New Orleans, changed there to a river steamer that should take them up the Mississippi and by the Ohio River to the distributing point of Cincinnati. Many delays might happen in such a long trip, and many delays did happen, and in several cases the reapers did not reach the farmers who had ordered them until long after the harvesting season was over. McCormick saw that he must build his reapers in a more central place.

At that time labor was very scarce in the great central region of the country, and the farms were enormous. The wheat was going to waste, for there were not enough scythes and sickles to cut it. McCormick started on a trip through the middle West, and what he saw convinced him that his reaper would soon be an absolute necessity on every farm. All he needed was to find the best point for building his machines and shipping them. He studied this matter with the greatest care, and finally decided that the strategic place was the little town of Chicago, situated on one of the Great Lakes, and half-way between the prairies of the West and the commercial depots and factories of the eastern seaboard.

Chicago in 1847 was still little more than a frontier town. It had fought gamely with floods and droughts,

with cholera and panics, with desperadoes and with land thieves. But men saw that it was bound to grow, for railroads would have to come to bring the wheat and others to carry it away, and that meant that some day it would be a great metropolis. McCormick, like most of the other business builders who were streaming into Chicago, only wanted credit to enable him to build and sell his goods, and he was fortunate enough to find a rich and prominent citizen named William B. Ogden, who was ready to give him credit and enter into partnership with him.

Ogden gave McCormick $25,000 for a half interest in the business of making reapers, and started at once to build a factory. At last the inventor was firmly established. He arranged to sell five hundred reapers for the harvest of 1848, and as one after another was sent out into the great wheat belts and set up and tried, the farmers who saw them decided that the reapers spelled prosperity for them. The business grew, and at the end of two years, when the partners found it wiser to dissolve their firm, McCormick was able to tell Ogden that he would pay him back the $25,000 that he had invested, and give him $25,000 more for interest and profits. Ogden accepted, and McCormick became sole owner of the business.

Cyrus McCormick was not only an inventor, but a business-builder of the rarest talent, one of the great pioneers in a field that was later to be cultivated in the United States to a remarkable degree. He knew he had a machine that would lessen labor and increase wealth wherever wheat was grown, and he felt that it

was his mission to see that the reaper should do its share in the progress of the world. In that sense he was more than a mere business man; but in another sense he was a gigantic business-builder. Just as he had studied the problem of cutting wheat with the object of producing the most efficient machine possible, so he now studied the problem of selling his reapers in such a way that every farmer should own one. He believed in liberal advertising, and he had posters printed with a picture of the reaper at the top, and below it a formal guarantee warranting the machine's performance absolutely. There was a space beneath this for the signature of the farmer who bought, and the agent who sold, and two witnesses. The price of the reaper was one hundred and twenty dollars, and the buyer paid down thirty dollars, and the balance at the end of six months, provided the reaper would cut one and a half acres an hour, and fulfil the other requirements. This guarantee, with a chance to obtain the money back if the purchase was unsatisfactory, was a new idea, and appealed to every one as a most sincere and honorable way of doing business. More than this, he sold for a fixed price, which was in many respects a new method of selling, and he printed in newspapers and farm journals letters he had received from farmers telling of their satisfaction with the reaper. In these new ways he laid the foundation of an enormous business.

The rush to the gold fields of California in 1849 and the resulting settlement of the far western country made Chicago even more central than it had been before.

But, although the advertisements of the McCormick reaper were scattered everywhere, many farmers would put off buying until the harvesting season had almost come, and when it was too late to get the machines from the central factory. Therefore McCormick had agents and built warehouses in every farming district, and these agents were given a free rein in their own locality, their instructions being to see that every farmer who needed a reaper was given the easiest opportunity to get one. The price was a fixed one, but McCormick was patient with the purchasers. He gave them a chance to pay for the reapers with the proceeds of their harvests. He held that it was better that he should wait for the money than that the farmers should lack the machines that would enable them to make the most of their fields of grain. "I have never yet sued a farmer for the price of a reaper," he stated in 1848, and he held to that policy as steadfastly as he could. As a result he soon gained the farmers' confidence, and his name became identified with square, and even with lenient, dealing with all classes of purchasers. He lost little by it, and in the long run the wide-spread advertising of this policy of business proved an invaluable asset.

It is not to be supposed that no rival reapers were put upon the market. Many were, and to meet some of these McCormick made use of what became known as the Field Test. He would instruct his agents to issue invitations to his rivals to meet him in competition. Then the different makes of reapers would show how many acres of grain they could cut in an afternoon

before an audience of the neighboring farmers. Judges were appointed to decide as to the merits of the different machines, and in most of the tests McCormick's reaper outdistanced all its rivals. In one such meeting it is said that forty machines competed. Such shows were the best possible form of advertising, but in time they degenerated into absurd performances. Trick machines of unwieldy strength were built secretly, and reapers were driven into growths of young trees, and were fastened together and then pulled apart to prove which was the stronger. At last it was realized that the field tests were no longer fair, and McCormick gave them up.

So important an invention as the reaper was certain to have many improvements made to it. For a number of years, however, the only additions that were made to the original model were seats for the driver and raker. The machine did the work of the original man with the sickle or scythe and that of the cradler, and having cut the grain left it in loose piles on the ground. But it still had to be raked up and bound, and a number of inventors were busy trying to perfect mechanical devices that would do this work too. A man named Jearum Atkins invented a contrivance that was called the "Iron Man," which was a post fastened to the reaper, having two iron arms that swept round and round and brushed the grain from the platform as fast as it was cut and had fallen. This plan was very clumsy, but improvements were made so rapidly that by 1860 the market was filled with various patterns of self-raking reapers.

The problem of binding the grain was more difficult. This had always been hard labor, taking a great deal of time and requiring three or four men to every reaper. The first step toward a self-binder was the addition of a foot-board at the back of the reaper, on which a man might stand and fasten the grain into sheaves as it fell. This was a little better than the old method, but only a little. It took less time, but it was still very hard and slow work.

McCormick was deep in a study of this matter when one day a man named James Withington came to him from Wisconsin, and announced that he had a machine that could automatically bind grain. McCormick had been working night and day over his own plan, and when the inventor began to explain he fell asleep. When he woke, Withington had left. McCormick at once sent one of his men to the inventor's Wisconsin home, and, with many apologies, begged him to come back. Withington did, and showed McCormick a wonderful machine, one made of two arms of steel that would catch each bundle of grain, pass a wire about it and twist the ends of the wire, cut it loose, and throw it to the ground. Here was an invention that would more than double the usefulness of the reaper, and one that seems quite as remarkable as the reaper itself. McCormick at once contracted with Withington for this binder, and tried it on an Illinois farm the following July. It worked perfectly, cutting fifty acres of grain and binding it into sheaves. At last only one person was needed to harvest the wheat, the one who sat upon the driver's seat and simply had to guide the

horses. A small boy or girl could do all the work that it had taken a score of men to accomplish twenty years before.

Now it seemed as if the reaper was complete, and nothing could be added to increase its efficiency. McCormick had seen to it that the whirr of his machine was heard in every wheat field of the United States, and was busily extending the reign of the reaper to the great grain districts of Russia, India, and South America. Then, in the spring of 1880, William Deering built and sold 3,000 self-binding machines that used twine instead of wire to fasten the sheaves, and as the news of this novelty spread the farmers declared that the wire of the old binders had cut their hands, had torn their wheat, had proved hard to manage in the flour-mills, and that henceforth they must have twine-binders.

McCormick realized that he must give the farmers what they demanded, and he looked about for a man who could invent a new method of binding with twine. He found him in Marquis L. Gorham, who perfected a new twine-binder, and added a device by which all the sheaves bound were turned out in uniform size. By the next year McCormick was pushing his Gorham binder on the market, and the farmers who had wavered in their allegience to his reaper were returning to the McCormick fold.

The battle of rival reapers had been long and costly. From the building of his factory in Chicago McCormick had been engaged in continuous lawsuits with competitors. His original patent had expired in 1848, and

he had used every effort to have it extended. The battle was fought through the lower courts, through the Supreme Court, and in Congress. The greatest lawyers of the time were retained on one side of the reaper struggle or the other. His rivals combined and raised a great fund to defeat his claims. He spent a fortune, but his patents were not renewed, and competition was thrown wide open. With the invention of the twine-binder the patent war burst out afresh, and again the courts were called upon for decisions between the rivals. But by now the competition had become so keen and the cost of manufacturing so heavy that the field dwindled quickly. When the war over the twine-binder ended there were only twenty-two competing firms left; before that there had been over a hundred.

The reaper had been primarily necessary in America, because here farm labor was very scarce, and the wheat fields enormously productive. In fact the growth of the newly opened Western country must have been indefinitely retarded if men had had to cut the grain by hand and harvest it in the primitive manner. The reaper was a very vital factor in the development of that country, and McCormick deserved the credit of being one of the greatest profit-builders of the land.

In Europe and Asia labor was plentiful, and the reaper had to win its way more slowly. McCormick showed his machine at the great international exhibitions and gradually induced the large landowners to consider it. Practical demonstration proved its value, and it made its appearance in the fields of European Russia and Siberia, in Germany and France and the

Slavic countries, in India, Australia, and the Argentine, and at last wherever wheat was to be cut. It trebled the output of grain, and the welfare of the people has proven largely dependent on their food supply. It has been an invention of the greatest economic value to the world.

XII

HOWE AND THE SEWING-MACHINE

1819–1867

THE needs of his times, and of the people among whom he lives, have often set the inventor's mind working along the line of his achievement. It was so with Elias Howe, who built the first sewing-machine. A hard-working man, and not overstrong, he would return to his home from the machine-shop where he was employed, and throw himself on the bed night after night to rest. Each night he watched his young wife sewing to clothe their three children and add a little something to the family income. With a strong taste for mechanics it was natural that he should wonder if there were not some way of lightening the burden of so much needlework.

He had been brought up in surroundings that naturally impressed him with the value of looms and new appliances for spinning and weaving. He understood the various processes of handling wool and cotton, although his own work lay outside them. His father had been a miller in the small Massachusetts town of Spencer, where Elias was born in 1819. New England was already building her textile factories, and when he was only six the boy joined his brothers and sisters at the work of sticking wire teeth through the straps of leather that were then used for cotton-cards.

What he learned from books he had to pick up during a few weeks each summer at the district school. His health was delicate, and he was lame, unfitted to be a farmer, and his best place seemed to be in his father's mill. But he was ambitious, and when he was sixteen, a friend having brought him glowing tales of the great cotton-mills in the fast-growing city of Lowell, he decided to seek his fortune there. The panic of 1837 closed the mills, and Howe found his course deflected to work in a machine-shop in Cambridge. By the time he came of age he had married and was living in Boston, working as a mechanic to support his family. Of a speculative turn of mind, he was constantly suggesting improvements at the shop, and his watching his wife labor with needle and thread turned his thoughts in the direction of a machine for sewing.

The idea was not a new one, but the men who had studied it had decided that there were too many difficulties to overcome. Howe took up the matter as a pastime, giving his spare moments to it, and talking it over with his wife in the evenings when he was not too tired. Naturally enough what he tried to do was to imitate the action of the hand in sewing. His idea was to make a machine that would thrust a needle through the cloth and then push it back again, working up and down. Therefore his first needle was sharp at both ends, and had its eye in the middle. He decided that he could only use very coarse thread, as the constant motion would surely snap any fine thread. But a year's experimenting convinced him that this simple up-and-down thrust was too primitive a motion, and

that the needle must be made to form a different sort of stitch. He tried one method after another, and finally hit upon the idea of making use of two threads, and forming the stitch by means of a shuttle and a curved needle having the eye near the point. He made a model, in wood and wire, of this first sewing-machine, in October, 1844, and found that it would work.

An early account of Howe's first sewing-machine says, "He used a needle and a shuttle of novel construction, and combined them with holding surfaces, feed mechanism, and other devices as they had never before been brought together in one machine. . . . One of the principal features of Mr. Howe's invention is the combination of a grooved needle having an eye near its point, and vibrating in the direction of its length, with a side-pointed shuttle for effecting a locked stitch, and forming with the threads, one on each side of the cloth, a firm and lasting seam not easily ripped."

Howe had now decided to give all his time to introducing his sewing-machine. He gave up his position in the machine-shop, and moved his family to his father's house in Cambridge. There his father was employed in cutting palm-leaf for the manufacture of hats. The son had a lathe put in the garret, and began to make the various parts that were needed for his sewing-machine. He did any work he could find by the day to supply his family with food and clothing, but it proved a very hard battle. His father's shop burned, and the whole family seemed on the brink of ruin. The young inventor was in a very difficult situa-

tion. He was confident that he had a machine that should, if properly handled, bring him in a fortune, but he must have some money to buy the iron and steel that were essential to its building, and he must devise a way of interesting some capitalist in it sufficiently to enable him to put it on the market. Meantime he must contrive to provide for his family, who were now practically without shelter.

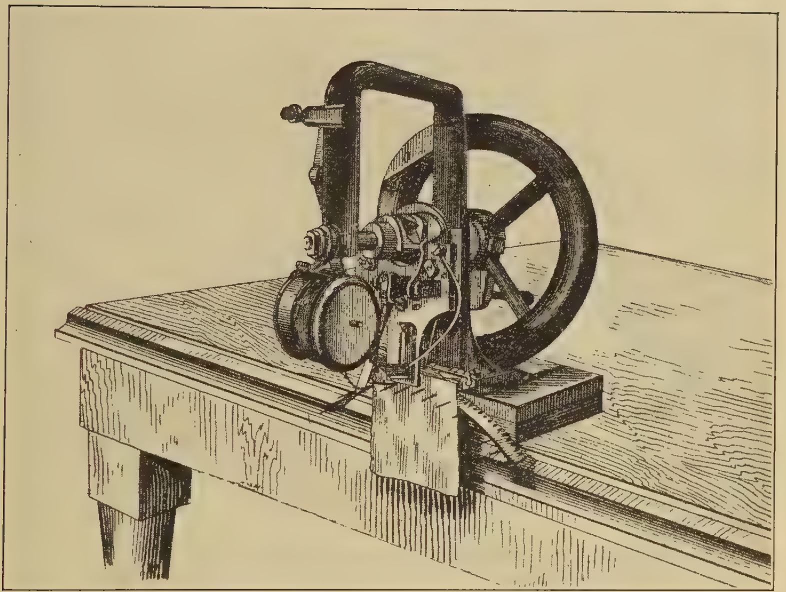
Fortunately, at this point, a Cambridge dealer in coal and wood, by the name of Fisher, heard of Howe's machine, and asked to see it. Howe jumped at the opportunity, explained its mechanism, and told how he was situated. Mr. Fisher thought the model had possibilities, and agreed to provide board for the inventor and his family, to give the young man a workshop in his own house, and to advance him the sum of $500, which Howe said was absolutely necessary to pay for the construction of such a machine as could be shown to the public. For his assistance Fisher was to receive a half-interest in a patent for the sewing-machine if Howe could obtain one. This arrangement proved Howe's salvation, and in December, 1844, he moved into his new friend's house.

He worked all that winter, meeting the many practical difficulties that arose as he progressed with his machine, and devising solutions for overcoming each. He worked all day, and many a time long into the night. His machine progressed so well that by April, 1845, he found that it would sew a seam four yards long. The machine was entirely completed by the latter part of May, and its work proved satisfactory to both partners.

Howe sewed the seams of two woolen suits with it, one for himself, and one for Fisher, and it was declared that the mechanical sewing was so well done that it promised to outlast the cloth. There was no longer any doubt that Howe had invented a machine that would lighten labor to a very great degree.

He took out his first patent on the sewing-machine toward the end of 1845. But when he tried to introduce his invention he met the same difficulties that had faced all men who tried to supplant hand labor by any mechanical process. The tailors of Boston to whom he showed it were willing to admit its efficiency, but told him that he could never secure its general use, as such a proceeding would ruin their business. Every one admired the sewing-machine and praised Howe's ingenuity, but no one would buy one. The opposition to the completed machine seemed insuperable, and Fisher, believing it to be so, at length withdrew from his partnership with Howe. The latter and his family had to move back again to his father's house.

To make a living Howe took a position as a locomotive engineer, leaving his invention unused at home. This work proved too hard, his health broke down, and he was compelled to give up the position. In his enforced idleness he began to devise new ways of selling his machine, and finally decided to send his brother Amasa to England, and see if he could not interest some one there in the invention. His brother was willing to do this, and arrived in London, with a sewing-machine, in October, 1846. He showed it to a man named William Thomas, who became interested



Elias Howe's Sewing Machine

in it, offered $1,250 for it, and also offered to employ Elias Howe in his business of umbrella and corset maker.

Howe decided that this position was preferable to his idleness in Cambridge, and accepted it. He sailed for England, and entered the factory of William Thomas. But, although Thomas had taken a very lively interest in Howe's sewing-machine, he did not treat the inventor well. For eight months Howe worked for him, and meantime he had sent for his wife and three children, and they had arrived in London. But eight months was the limit of his endurance of his new master's tyranny, and at the end of that time he gave up his position. Matters seemed tending worse and worse with him, and the situation of the Howe family in London, almost penniless, grew daily more and more precarious.

His family at home sent Howe a little money before his earnings were entirely spent, and he used this to buy passage for his wife and children back to the United States. He himself stayed in London, believing there were better chances for the sale of his machine there than in America. But his pursuit of fortune in England proved but the search for the rainbow's pot of gold. There was no market for his wares, and after months of actual destitution he pawned the model of his sewing-machine and even his patent papers in order to secure funds to pay his passage home. Tragedy dogged his footsteps. He reached New York with only a few small coins in his pocket, and received word that his wife was lying desperately ill in Cambridge. His own strength was spent, and he had to wait several days before he had the money to pay his railroad fare

to Boston. Soon after he reached home his wife died. Blow after blow had fallen on him until he was almost crushed.

Even his hard-won invention seemed now about to be snatched from him. Certain mechanics in New England, who had heard descriptions of his model, built machines on its lines, and sold them. The newspapers learned of these, and began to suggest their use in a number of industries. Howe looked about him, saw the sewing-machine growing in favor, heard it praised, and realized that it had been actually stolen from him. He bestirred himself, found patent attorneys who were willing to look into his patents, and when they pronounced them unassailable, found money enough to defend them. He began several suits to establish his claims in August, 1850, and at about the same time formed a partnership with a New Yorker named Bliss, who agreed to try to sell the machines if Howe would open a shop and build them in New York.

Howe's claims to the invention of the sewing-machine were positively established by the courts in 1854. The machine was now well known, and its value as a money-maker very apparent. But the workers in cheap clothing shops organized to prevent the introduction of the machines, claiming that they would destroy their livelihood. Labor leaders took up the slogan, and led the men and women workers in what were known as the Sewing-machine Riots. In the few shops where the machines were actually introduced they were injured or destroyed by the workmen. The pressure became so great that the larger establishments ceased their use,

and only the small shops, that employed a few workers, were able to continue using the new machine. In spite of its recognized value it looked as if the sewing-machine could not prove a financial success, and when Howe's partner Bliss died in 1855 the inventor was able to buy his share in the business from his heirs for a very small sum.

Opposition, even of the most strenuous order, has never been able to retard for long the use of an invention that simplifies industry. If a machine is made that will in an hour do the work that formerly required several days' hand labor that machine is certain to displace that hand labor. The workers may protest, but industrial progress demands the more economic method. So it was with the sewing-machine. The riots died away, the labor leaders turned to other fields, and one by one the clothing factories installed the new machines. Howe had the patience to wait, and in one way and another obtained the sinews of war to sue the infringers of his patents. The waiting was worth while. He ultimately forced all other manufacturers of sewing-machines to pay him for their products. In six years his royalties increased from $300 a year to over $200,000 a year. His machine was shown at the Paris Exposition of 1867, and was awarded a gold medal, and Howe himself was given the ribbon of the French Legion of Honor.

The wheel of fortune has turned quickly for many inventors, but perhaps never more completely than it did for Elias Howe. The man who had pawned his goods in London, and had reached New York with less

than a dollar in his pocket, had an income of $200,000 a year. He who had been rebuffed by the tailors of Boston was recognized as one of the great men of his generation, and one who, instead of taking the bread from the mouths of poor working men and women, had lightened their labor a thousandfold. The women, like his own wife, who had sewed by day and night, were saved their strength and vision, and the slavery of the clothing factories, notorious in those days, was inestimably lightened. But it had been a hard fight to make the world take what it sorely needed.

Howe's struggle had been so hard that his health was badly broken when he did succeed. He had several years to enjoy his profits and honors. He died October 3, 1867, at his home in Brooklyn.

Many inventors have barely escaped with their lives from the fury of mobs who thought the inventor would take their living from them. Papin, and Hargreaves, and Arkwright all learned what such resistance meant. But as one invention has succeeded another people have grown wiser, and realized that each has conferred a benefit rather than taken away a right. Howe was one of the last to find the people he hoped to benefit aligned against him. The world has moved, since Galileo's day, and the inventor is now known as the great benefactor. But Howe's life was a fight, and his triumph that of one of the great martyrs of invention.

XIII

BELL AND THE TELEPHONE
1847–

None of the inventions that have resulted from the study of electricity have been stumbled upon in the dark. Scientists in both England and America had realized the possibility of the telegraph before Morse built his first working outfit in his rooms on Washington Square. Edison took out a patent covering wireless telegraphy before Marconi gave his name to the new means of communication. Often a man who has been following one trail through this new field has come upon another, glanced down it, and decided to go back and explore it more thoroughly another day. Meantime the trail is run down by a rival. The prize has gone to that persevering one who has made that trail his own, and learned its secret while other men were only glancing at it. Alexander Graham Bell was by no means the first man to realize that the sound of the human voice could be sent over a wire. He did not happen to stumble upon this fact. He worked it out bit by bit, from what other men had already learned concerning electricity, and his object was to make the telephone of real use to the world. It so happened that Elisha Gray and Bell each filed a claim upon the telephone at the Patent Office on the same day,

February 14, 1876. But it was Bell who was able to place the first telephone at the public's service.

He came of a family that had long been interested in the study of speech. His father, his grandfather, his uncle, and two brothers had all taught elocution in one form or another at the Universities of Edinburgh, Dublin, and London. His grandfather had worked out a successful system to correct stammering, his father, widely known as a splendid elocutionist, had invented a sign-language that he called "Visible Speech," which was of help to those learning foreign tongues, and also a system to enable the deaf to read spoken words by the movements of the lips. Naturally enough the young inventor started with a very considerable knowledge of the laws of sound.

Bell was born in Edinburgh March 1, 1847, and educated there and in London. When he was sixteen family influence was able to get him the post of teacher of elocution in certain schools, and he spent his leisure hours studying the science of sound. Soon after he came of age he met two well-known Englishmen who were experts in his line of study, Sir Charles Wheatstone and Alexander J. Ellis. Ellis had translated Helmholtz's celebrated book on "The Sensations of Tone," and was able to show Bell in his own laboratory how the German scientist had succeeded in keeping tuning-forks in vibration by the power of electro-magnets, and had blended the tones of several tuning-forks so as to produce approximately the sound of the human voice. This idea was new to Bell, and led him to wonder whether it would not be possible to construct

what might be called a musical telegraph, sending different notes over a wire by electro-magnetism, using a piano keyboard to give the different notes.

Sir Charles Wheatstone, the leading English authority on the telegraph, received young Bell with the greatest interest, and showed him a new talking-machine that had been constructed by Baron de Kempelin. Bell studied this closely, discussed it with Wheatstone, and decided that he would devote himself to the problems of reproducing sounds mechanically.

The course of his life was then suddenly altered. His two brothers died in Edinburgh of consumption, and he was told that he must seek a change of climate. Accordingly his father and mother sailed with him to the town of Brantford in Canada. There he at once became interested in teaching his father's system of "Visible Speech" to a tribe of Mohawk Indians in the neighborhood.

He had already had very considerable success in teaching deaf-mutes to talk by visible speech, or sign-language, and this success was repeated in Canada. Word of it went to Boston, and as a result the Board of Education of that city wrote to him, offering to pay him five hundred dollars if he would teach his system in a school for deaf-mutes there. He was glad to accept, and in 1871 moved to Boston, which he planned to make his permanent residence.

Success crowned his teaching almost immediately. Boston University offered him a professorship, and he opened a "School of Vocal Physiology," which paid him well. Most of his remarkable skill in teaching the

deaf and dumb to understand spoken words and in a manner to speak themselves was due to his father's system, which he had carefully followed, and had in some respects improved upon.

At this time a resident of Salem, Thomas Sanders, engaged the young teacher to train his small deaf-mute son, and asked him to make his home at Sanders' house in Salem. As he could easily reach Boston from there Bell consented, and in the cellar of Mr. Sanders' house he set up a workshop, where for three years he experimented with tuning-forks and electric batteries along the line of his early studies in London.

At nearly the same time Miss Mabel Hubbard came to him to be taught his system of speech. He became engaged to her, and some years later they were married.

His future wife's father was a well-known Boston lawyer, Gardiner G. Hubbard. It is related that one evening as Bell sat at the piano in Mr. Hubbard's home in Cambridge, he said, "Do you know that if I sing the note G close to the strings of the piano, the G-string will answer me?" "What of it?" asked Mr. Hubbard. "Why, it means that some day we ought to have a musical telegraph, that will send as many messages simultaneously over one wire as there are notes on the piano."

Bell knew the field of his work in a general way, but he had not yet decided which path to choose of several that looked as if they might lead across it. His far-distant goal was to construct a machine that would carry, not the dots and dashes of the telegraph, but the complex vibrations of the human voice. This would

be much more difficult to attain than a musical telegraph, and for some time he wavered between the two ideas. His work with his deaf and dumb pupils was all in the line of making sound vibrations visible to the eye. He knew that with what was called the phonautograph he could get tracings of such sound vibrations upon blackened paper by means of a pencil or marker attached to a vibrating cord or membrane, and furthermore that he could obtain tracings of certain vowel sound vibrations upon smoked glass. He studied the effect of vibrations upon the bones of the ear, and this led him to experiment with vibrating a thin piece of iron before an electro-magnet.

His study of the effect of vibrations on the human ear-drum showed Bell what path he should follow. Sound waves striking the delicate ear-drum could send thrills through the heavier bones inside the ear. He thought that if he could construct two iron discs, which should be similar to the ear-drums, and connect them by an electrified wire, he might be able to make the disc at one end vibrate with sound waves, send those vibrations through the wire to the other disc, and have that give out the vibrations again in the form of sounds. That now became his working idea, and it was the principle on which the telephone was ultimately to be built.

But Bell had been giving so much time and attention to this absorbing project that his teaching had suffered. His "School of Vocal Physiology" had had to be abandoned, and he found that his only pupils were Miss Hubbard and small George Sanders. Both Mr. Sanders and Mr. Hubbard, who had been helping him

with the cost of his experiments, refused to do so any longer unless he would devote himself to working out his musical telegraph, in which both had a great deal of faith as a successful business proposition.

While he was struggling with these distracting calls of duty and science he was obliged to go to Washington to see his patent attorney. There he determined to call upon Professor Joseph Henry, who was the greatest American authority on electrical science, and who had experimented with the telegraph in the early years of the century. Bell, aged twenty-eight, explained his new idea to Henry, then aged seventy-eight. The theory was new to Henry, but he saw at once that it had tremendous possibilities. He told Bell so. "But," said Bell, "I have not the expert knowledge of electricity that is needed." "You can get it," answered Henry. "You must, for you are in possession of the germ of a great invention."

Those few words, coming from such a man, were of the greatest possible encouragement to Bell. He returned home, determined to get the knowledge of electricity he needed, and to carry on his work with the telephone.

He rented a room at 109 Court Street, Boston, for a workshop, and took a bedroom in the neighborhood. He studied electricity night and day, and he gave equal time to the musical telegraph that his friends favored and to the invention that now claimed his real interest.

The man from whom Bell rented his workshop was Charles Williams, himself a manufacturer of electrical

supplies. Bell had for his assistant Thomas A. Watson, who helped him construct the two armatures, or vibrating discs, at the end of an electrified wire that stretched from the workshop to an adjoining room. Watson was working with Bell on an afternoon in June, 1875. Bell was in the workshop, and Watson in the next room. Bell was stooping down over the instrument at his end of the wire. Suddenly he gave an exclamation. He had heard a faint twang come from the disc in front of him.

He dashed into the next room. "Snap that reed again, Watson," he commanded. Back at his own end of the wire he waited. In a minute he caught the light twang again. It was only what he had been expecting to hear at any time during the months of his work, but nevertheless he was amazed when he did catch the sound. It proved that a sound could be carried over a wire, and accurately reproduced at the farther end. And that meant that the vibrations of the human voice could ultimately be sent in the same way.

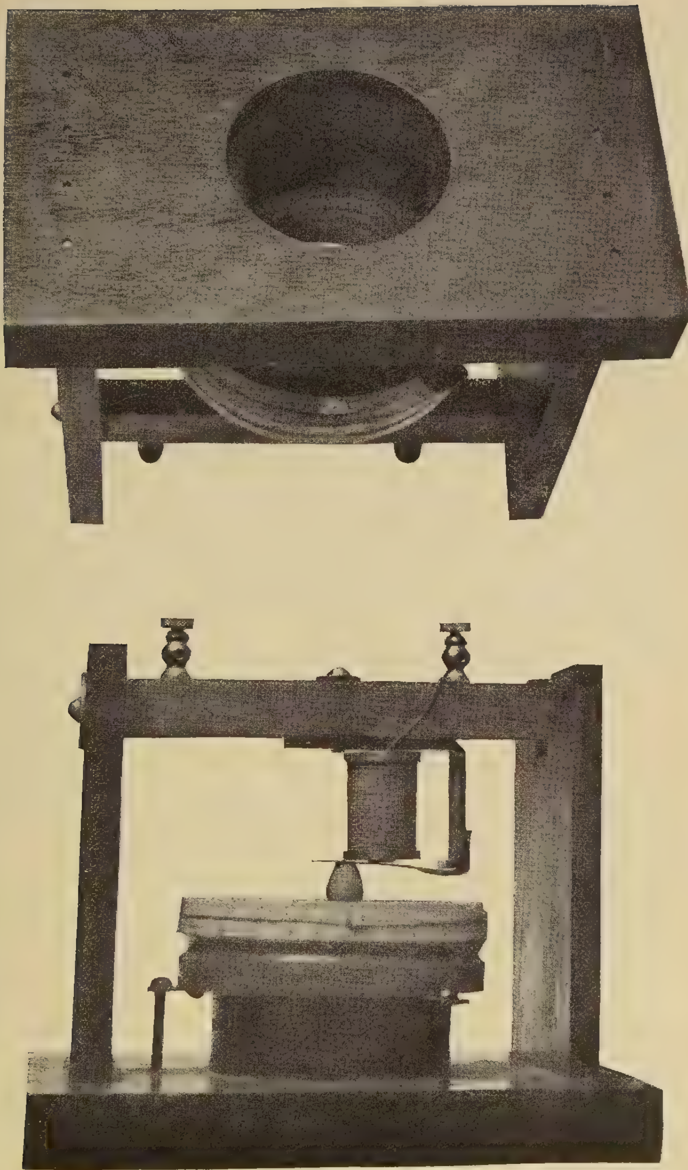
Bell's enthusiasm had already converted his assistant, Watson; it now won over Hubbard and Sanders. They began to believe that there might be something of real value in his strange scheme, and offered to help him finance it. He went on with his studies in electricity, and gradually began to learn how he could make it serve him best.

But it was a far cry from that first faint sound to the actual transmission of words. For a long time his receiving instruments would only give out vague rumbling noises. In November, 1875, his experiments

showed him that the vibrations created in a reed by the human voice could be transmitted in such a way as to reproduce words and sounds. Then, in January, 1876, he showed a few of the pupils at Monroe's School of Oratory in Boston an apparatus by which singing could be carried more or less satisfactorily from the cellar of the building to a room on the fourth floor. But on March 10, 1876, the new instrument actually talked. Watson, who was at the basement end of the wire, heard the disc say, "Mr. Watson, come here, I want you." He dashed up the three flights of stairs to the room in which Bell was. "I can *hear* you!" he cried. "I can *hear the words!*"

"Had I known more about electricity, and less about sound," Bell is reported to have said, "I would never have invented the telephone." He had come upon his discovery by the right path, but it was a path that very few men could ever have picked out. Other inventors had tried to make a machine that would carry the voice, but they had all worked from the standpoint of the telegraph. Bell, inheriting unusual knowledge of the laws of speech and sound, came from the other direction. He started with the laws of sound transmission rather than with the laws of the telegraph. The result was that he had created something altogether new, basically different from all the other inventions that made use of electricity, for which there was as yet no common name even, and which he described in his application for a patent, as "an improvement in telegraphy."

Only two months after the day on which the tele-



THE FIRST TELEPHONE

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From "The History of the Telephone"
By Herbert N. Casson
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phone had actually talked for the first time the Centennial Exposition opened in Philadelphia. Mr. Hubbard was one of the Commissioners, and he obtained permission to have Bell's first telephone placed on a small table in the Department of Education. Bell himself was too poor to be able to go to Philadelphia, and intended to stay in Boston, and try to find new deaf-mute pupils. But when Miss Hubbard left for the Centennial, and begged him to go with her, he could not resist. He stayed on the train, without a ticket, without baggage, and reached Philadelphia with the Hubbards.

The new instrument had been at the Exposition for six weeks without attracting serious attention. But Mr. Hubbard arranged that the judges should examine it for a few minutes on the Sunday afternoon following Bell's arrival. The afternoon, however, was very warm, and there were a great many exhibits for the judges to inspect. There was the first grain-binder, and the earliest crude electric light, and Elisha Gray's musical telegraph, and exhibits of printing telegraphs. It was seven o'clock when the judges reached Bell's table, and they were tired and hungry. One of the judges picked up the receiver, looked at it, and put it back on the table. The others laughed and joked as they started to go by. Then they stopped short. A man had come up to the table, with a crowd of attendants at his heels. He said to the young man at the table, "Professor Bell, I am delighted to see you again." The new arrival was the Emperor Dom Pedro of Brazil, who had once visited Bell's school for deaf-mutes in

Boston. The Emperor said he would like to test Bell's new machine.

With the judges, a group of famous scientific men, and the Emperor's suite for audience, Bell went to the transmitter at the other end of the wire, while Dom Pedro put the receiver to his ear. There was a moment's pause, and then the Emperor threw back his head, exclaiming, "*My God—it talks!*"

The Emperor put down the receiver. Joseph Henry, who had encouraged Bell in Washington, picked it up. He too heard Bell's own words coming from the disc. He too showed his amazement. "This comes nearer to overthrowing the doctrine of the conservation of energy," said he, "than anything I ever saw." After him came Sir William Thomson, later known as Lord Kelvin. He had been the engineer of the first Atlantic Cable. He listened intently. "Yes," said he at last, "it does speak. It is the most wonderful thing I have seen in America!"

Until ten o'clock that night the judges spoke into the transmitter and listened at the receiver of Bell's instrument. Next morning it was given a place of honor, and every one begged for a chance to examine it. It became the most wonderful exhibit of the Centennial, and the judges gave Bell their Certificate of Award. Nothing more opportune could possibly have happened for the inventor.

But in spite of this launching at the hands of the most eminent scientists, business men could see little future for the new machine. It was very ingenious, they admitted, but it could only be a toy. And Bell

himself was not sufficiently well versed in business affairs to know how to make the most of his invention. Fortunately Mr. Hubbard was much better acquainted with business methods. He determined to promote the telephone, and he did. He talked about it to all his friends until they could think of nothing else. He began a campaign of publicity, with the object of making the name of the new instrument a household word. He had it written up for the newspapers, and advertised public demonstrations of its powers, and arranged that Bell should lecture on it in different cities. Bell was a good lecturer, and his talks became popular. Then news was sent to the *Boston Globe* by telephone, and people began to wonder if there were not new possibilities in its use.

In May, 1877, a man named Emery called at Hubbard's office, and leased two telephones for twenty dollars. That encouraged the promoters, and they issued a little circular describing the business. Then another man, who ran a burglar-alarm company, obtained permission to hang up the telephone in a few banks. They proved of use, and the same man started a service among the express companies. Before long several other small exchanges were opened, and by August, 1877, it was estimated that there were 778 telephones in use. Hubbard was very much encouraged, and he, together with Bell, Sanders, and Watson formed the "Bell Telephone Association."

The Western Union Telegraph Company was a great corporation, controlling the telegraph business of the country. Hubbard hoped that it would purchase

the Bell patents, as it had already bought many patents taken out on allied inventions. They offered them to President Orton for $100,000, but he refused to buy them, saying, "What use could this company make of an electrical toy?"

But the Western Union had many little subsidiary companies, supplying customers with printing-telegraphs and dial telegraphs and various other modifications of the usual telegraph, and one day one of these companies reported that some of their customers were preferring to use the new telephone. The Western Union bestirred itself at this sign of competition, and had shortly formed the "American Speaking-Telephone Company," with a staff of inventors that included Edison. The war was on in earnest, for the new company not only claimed to have the best instrument on the market, but advertised that it had "the only original telephone."

That war was actually a good thing for Bell, and Hubbard, and Sanders. With the Western Union pushing this new invention, and not only pushing it, but fighting for its claim to it, the public realized that the telephone was neither a toy nor a scientific oddity, but an instrument of great commercial value. Sanders' relatives came to the aid of the Bell Company, and put money into its treasury, and soon Hubbard was leasing out telephones at the rate of a thousand a month.

But none of these partners was exactly the man to organize and build up such a business as this of the telephone should be, and each of them knew it. Then Hubbard discovered a young man in Washington who

impressed him as having remarkable executive ability. Watson met him, and his opinion coincided with that of Hubbard. The upshot of the matter was that the partners offered the post of General Manager at a salary of thirty-five hundred dollars a year to this man, Theodore N. Vail, and Vail accepted the offer. Vail himself knew little about the telephone, but his cousin, Alfred Vail, had been the friend and assistant of Morse when he was working on his first telegraph.

Hubbard had advertised Bell's telephone, Sanders had financed it, and now Vail pushed it on the market. He faced the powerful Western Union and fought them. He sent copies of Bell's original patent to each of his agents, with the message, "We have the only original telephone patents, we have organized and introduced the business, and we do not propose to have it taken from us by any corporation."

His plan was to create a national telephone system, and so he confined each of his agents to one place, and reserved all rights to connect one city with another. He made short-term contracts, and tried in every way to keep control of the whole system in the hands of the parent company. Then the Western Union came out with Edison's new telephone transmitter, which increased the value of the telephone tenfold, and which in fact made it almost a new instrument. The Bell Company was panic-stricken, for their customers demanded a telephone as good as Edison's.

Those were hard times for Vail and the partners back of him. The telephone war had cut the price of service to a point where neither company could show a profit.

Bell, now married, returned from England with word that he had been unable to establish the telephone business there, and that he must have a thousand dollars at once to pay his most pressing debts. He was ill, and he wrote from the Massachusetts General Hospital, "Thousands of telephones are now in operation in all parts of the country, yet I have not yet received one cent from my invention. On the contrary, I am largely out of pocket by my researches, as the mere value of the profession that I have sacrificed during my three years' work amounts to twelve thousand dollars."

At this juncture a young Bostonian named Francis Blake wrote to Vail, announcing that he had invented a transmitter that was the equal of Edison's, and offering to sell it for stock in the company. The purchase was made, and the claim of the inventor proved true. The Bell telephone was again as good as that of the Western Union Company. A new company, called the National Bell Telephone Company, was organized, with a capital of $850,000, and Colonel Forbes of Boston became its first president.

There have been few patent struggles to compare with that which was waged over the telephone. McCormick fought for years to uphold his rights to the invention of the reaper, but he fought a host of competitors, and the warfare was of the guerrilla order. The Bell Company fought alone against the Western Union, and it was a struggle of giants. The Western Union was certain that it could find patents antedating Bell's, and it went on that assumption, even after its own expert had reported, "I am entirely unable to

discover any apparatus or method anticipating the invention of Bell as a whole, and I conclude that his patent is valid." It claimed that Gray was the original inventor, and instructed its lawyers to bring suits against the Bell Company for infringing on Gray's patents.

The legal battle began in the autumn of 1878, and continued for a year. Then George Gifford, the leading counsel for the Western Union, told his clients that their claim was baseless, and advised that they come to a settlement. The Western Union saw the wisdom of this course, and went to the Bell Company with an offer of compromise. An agreement was finally reached, to remain in force for seventeen years, and the terms were that the Western Union should admit that Bell was the original inventor, that his patents were valid, and should retire from the telephone business. On the other side, the Bell Company agreed to buy the Western Union telephone system, to pay them a royalty of twenty per cent. on all their telephone rentals, and to keep out of the telegraph business.

That ended the great war. It converted a powerful rival into an ally, it gave the Bell Company fifty-six thousand new telephones in fifty-five cities, and it made that company the national system of the United States. In 1881 there was another reorganization; the American Bell Telephone Company was created, with a capital of six million dollars. The following year there was such a telephone boom that the Bell Company's system was doubled, and the gross earnings reached more than a million dollars.

The four men who had taken hold of Bell's invention in its infancy and brought it to maturity were ready to surrender its care into the hands of the able business men who headed the Bell Company. Sanders sold his stock in the company for a little less than a million dollars, Watson, when he resigned his interest, found himself sufficiently rich to build a ship-building plant near Boston and employ four thousand workmen to build battle-ships. Gardiner G. Hubbard retired from active business life, and transferred his remarkable energy to the affairs of the National Geographical Society. Bell had presented his stock in the company to his wife on their wedding-day, and he now took up afresh the work of his boyhood and youth, the teaching of deaf-mutes. But he was no longer unheeded nor unrewarded. In 1880 the government of France awarded him the Volta prize of fifty thousand francs and the Cross of the Legion of Honor. With the Volta prize he founded the Volta Laboratory in Washington for the use of students. In Washington he has made his home, and there scientists of all lands call to pay their respects to the patriarch of American inventors.

Shortly after the first appearance of the telephone at the Centennial Exposition men were accustomed to laugh at the new invention, and call it a freak, a scientific toy. Its mechanism was so incomprehensible to most people that they refused to regard it seriously. A Boston mechanic expressed the general ignorance when he stoutly maintained that in his opinion there must be "a hole through the middle of the wire."

And the telephone is still to most people a mystery, far more so than the telegraph or the incandescent light or the other uses to which electricity has been put. It is one thing to send a message by the mechanical process of dots and dashes made by breaking and joining a current. It is quite another to reproduce in one place the exact inflection, tone, and quality of a voice that is speaking hundreds of miles away, across rivers and mountains. There is real magic in that, the wonder that might be found in a Genii's spell in the Arabian Nights. How can people be blamed for laughing at such pretensions, and believing that even if such a thing were true it was more fit for an exposition than for public use?

Yet this thing of magic has outdistanced every other mode of communication. It is estimated that in the United States as many messages are sent by telephone as the combined total of telegrams, letters, and railroad passengers. The telephone wires are eight times greater than the telegraph wires, and their earnings six times as great. It is true that the telephone is vastly more used in America than in other parts of the world, and yet it is figured that in the world at large almost as many messages are now telephoned as are sent by post.

And the mystery of the telephone grows no less the more one studies it. You speak against a tiny disc of sheet-iron, and the disc trembles. It has millions and millions of varieties of trembles, as many as there are sounds in the universe. A piece of copper wire, connected with an electric battery, stretches from the disc against which you have spoken to another disc

miles and miles away. The tremble of your disc sends an electric thrill along the wire to that other disc and makes it tremble exactly as yours did. And that trembling sounds the very note you spoke, the very note in millions of possible notes, and as accurately as if the sound wave had only traveled three feet through clear air. That is what happens when you telephone, but when you realize it the mystery gains rather than decreases.

Scores of men claimed to have invented telephones before Bell did, but none ever proved their claims. Men who were studying improvements on the telegraph had glimpses of the ultimate possibility of transmitting speech by wire, and Elisha Gray filed a caveat on that point later on the very day that Bell filed his application for a patent. But Gray's was a caveat, or a declaration that the applicant believes he can invent a certain device, and Bell's was the statement that he had already perfected his invention. Bell's claim stood against the world, and men now recognize that the telephone was born on that afternoon in June, 1875, when the young teacher of deaf-mutes first caught the faint twang of a snapping reed sent across a few yards of wire.

XIV

EDISON AND THE ELECTRIC LIGHT

1847–

TO some men the material world is always presenting itself in the form of a series of fascinating puzzles, to be solved as one might work out a game of chess. The astronomer is given certain figures, and from those he intends to derive certain laws; the scientist knows the properties of certain materials and from those he is to reach some new combination that will produce a new result. He is not an inventor as much as he is a detective; he picks up the clews to certain happenings and constructs a working theory to fit them. In mechanics this theory that he constructs usually takes the form of a machine. And this machine is not so much a new discovery as it is the practical working-out of certain carefully-selected laws of nature.

Perhaps there has never been a man whose thoughts were so continually asking the question why as Thomas Alva Edison. Certainly there has never been one who has found the answer to that question in so many lines of scientific study. He has not merely happened on his discoveries. He has not been as much interested in the result as in the reasons for it. He belongs to the experimenting age. Once on a time men took the

facts of nature for granted. But if they had always done so there would have been no telegraph, no telephone, no electric light, no phonograph. Each of these were achieved by working on a definite problem, and in no haphazard way. The inventor has become a scientist and a mechanic, and no longer an amateur discoverer. Chance has much less to do with the winning of new knowledge than it once had.

A visitor to Edison's laboratory tells how he found him holding a vial of some liquid to the light. After a long look at it he put the vial down on the table, and resting his head in his hands, stared intently at it, as if he expected the vial to make some answer. Then he picked it up, shook it, and held it again to the light. The visitor introduced himself. Edison nodded toward the bottle. "Take a look at those filings," said he. "See how curiously they settle when I shake the bottle. In alcohol they behave one way, but in oil in this way. Isn't that the most curious thing you ever saw—better than a play at one of your city theatres, eh?" Again he shook the vial. "What I want to know is what they mean by it; and I'm going to find out." There is the man, he wants to know "what they mean by it," he continually asks the question why, he is the great experimenter among great inventors.

Edison has shown the calibre of his mind in a score of different ways. He has been showing it ever since the days when he was a newsboy on the trains of the Canadian Grand Trunk Railroad and the Michigan Central. Then he fitted up a corner of the baggage-car of his train as a miniature laboratory, and filled it

with the bottles and retorts that had been discarded at the railroad workshops. Among his treasures was a copy of Fresenius's "Qualitative Analysis," engaging reading for a boy only twelve years old. But he was not only a chemist. When he was not working on the train he would be hanging about machine shops, listening and watching and considering. One day the manager of the *Detroit Free Press* told him he might have some three hundred pounds of old type that had been used up. The newsboy found an old hand-press and began to print a paper himself, called the *Grand Trunk Herald*, and sold it to the employees and regular passengers on his line. Usually he would set the type before the train started, and print it in the spare moments of his trip. Sometimes one of the station-masters on the run, who was also a telegraph operator, would get a piece of important news, write it down, and hand the paper to Edison as the train stopped. Then the boy would go to his shop in the caboose, set up the item, print it, and sell it, beating the daily newspapers that might be awaiting the passengers at the end of the ride.

The new invention of the telegraph, and the great possibilities of its use, early caught his attention. About the time the Civil War began the newsboy adopted a new idea in his business. He had always found it difficult to know how many newspapers to carry on each trip. If he had too large a stock some would be left on his hands, if he carried too few he would be sold out early and lose a good profit. He made a friend of one of the compositors of the *Detroit Free Press*, and got

him to show him the proofs of the paper. That gave him some idea of the news of the day, and he could judge how many papers he would probably need. One day the proof-slip told him that there had been a terrific battle at Pittsburg Landing, or Shiloh, and that sixty thousand men had been killed and wounded. He knew that this would sell the paper. All he needed was to let people get an inkling of what the news was.

Edison dashed to the telegraph-operator and asked if he would wire a message to each of the large stations on the railroad line requesting the station-masters to chalk up a notice on their train bulletin-board, giving the fact that there had been a great battle, and that papers telling about it would reach the station at such an hour. In return he offered the operator newspaper service for six months free. The bargain was made, and the boy hurried to the newspaper office.

He did not have enough money to buy as many papers as he wanted. He asked the superintendent to let him have one thousand copies of the *Press* on credit. The request was instantly refused. Thereupon he marched up the stairs to the office of the paper's owner, and asked if he would give him fifteen hundred copies on trust. The owner looked at the boy for a moment, and then wrote out an order. "Take that down-stairs," said he, "and you will get what you want." As Edison said in telling the story afterward, "Then I felt happier than I have ever felt since."

He took his fifteen hundred copies to his storehouse on the train. At the station where the first stop was made he usually sold two papers. That day as they

ran in to the platform it looked as if a riot had occurred. All the town was clamoring for papers. He sold a couple of hundred at five cents each. Another crowd met him at the next stop, and he raised his price to ten cents a copy. The same thing happened at each place where they stopped. When he reached Port Huron he put what was left of his stock in a wagon, and drove through the main streets. He sold his papers at a quarter of a dollar and more apiece. He went by a church, and called out the news of the battle. In ten seconds the minister and all his congregation were clamoring about the wagon, bidding against each other for copies of the precious issue. He had made a small fortune for a boy, and felt that he owed it largely to his use of the telegraph. Quick-witted he was, beyond a doubt, of an inventive turn, but a shrewd business man on top of all.

He wanted to be a telegraph-operator. Electricity fascinated him, and he could watch the machines and listen to the music of their clicking by the hour. He set up a line of his own in his father's basement at Port Huron, making his batteries of bottles, old stovepipe wire, nails and zinc that he could pick up for a trifle. He studied the subject in his shop in the corner of the baggage-car, during the scant moments when he was neither printer nor newsboy. Once a bottle of phosphorus upset and started a fire. The boy was thrashed and his bottles and wires thrown out. But he was too doggedly persistent to mind any mishap. He saved the small son of the station-master at Port Clements from being run down by a train, and in return the father of-

fered to teach him telegraphy. So little by little he learned his chosen work.

He obtained a position as night operator at Port Huron. That kept him busy at night, but he refused to sleep during the daytime as other night operators did, and used that time to work on his own schemes. To catch some sleep he kept a loud alarm-clock at his office, and set it so that he would be wakedwhen trains were due and he was needed. But sometimes trains were off schedule, and again and again he would oversleep. At last the train despatcher ordered Edison to signal him the letter "A" in the Morse alphabet every half hour. The boy willingly agreed. A few nights later he brought an invention of his own to the office, and connected it by wires with the clock and the telegraph. Then he watched it work. Exactly on the half hour a little lever fell, sending an excellent copy of the Morse "A" to the key of the telegraph. Another lever closed the circuit. He kept his eyes on this instrument of his making until he had seen it act faultlessly again at the next half hour. Then he went to sleep. Night after night the signal was sent without a mistake, and the despatcher began to regain some of the confidence he had lost in the young operator. Then one night the despatcher chanced to be at the next station to Edison's, and it occurred to him to call the latter up and have a chat with him. He signaled for fifteen minutes, and received no answer. Then he jumped on a hand-car and rode to Edison's station. Looking through the window he saw the youth sound asleep. His eyes took in the strange instrument upon the table. It was near

the half hour, and as the man watched he saw one lever of the instrument throw open the key and the other send the signal over the wire. The operator was still sleeping soundly. The despatcher recognized the young man's ingenuity, but he also realized that he had been fooled, and so he woke Edison none too gently, and told him that his services were no longer in demand on that road.

Ingenuity, mechanical short-cuts, new devices for doing old work, were what beset his mind. He was not interested in doing the simple routine service of a telegrapher, he wanted to see what improvements on it he could make. Often this keenness for new ideas led him into trouble with his employers; occasionally it was of real service. At one time an ice-jam had broken the cable-line between Port Huron, in Michigan, and Sarnia, over the Canadian line. The river there was a mile and a half wide. The officers were wondering how they could get their messages across when they saw Edison jump upon a locomotive standing in the train-yard. He seized the valve that controlled the whistle. He opened and closed it so that the locomotive's whistles resembled the dots and dashes of the telegraph code. He called Sarnia again and again. "Do you hear this? Do you get this?" he sent by the whistle. Four and five times he sent the message, and finally the whistle of a locomotive across the river answered him. In that way communication was again established.

A little later, when Edison was employed as operator in the railroad office at Indianapolis, he practiced re-

ceiving newspaper reports in his spare hours at night. He and a friend named Parmley would take the place of the regular man, who was glad to have them do it. "I would sit down," said Edison, "for ten minutes, and 'take' as much as I could from the instrument, carrying the rest in my head. Then while I wrote out, Parmley would serve his turn at 'taking,' and so on. This worked well until they put a new man on at the Cincinnati end. He was one of the quickest despatchers in the business, and we soon found it was hopeless for us to try to keep up with him. Then it was that I worked out my first invention, and necessity was certainly the mother of it.

"I got two old Morse registers and arranged them in such a way that by running a strip of paper through them the dots and dashes were recorded on it by the first instrument as fast as they were delivered from the Cincinnati end, and were transmitted to us through the other instrument at any desired rate of speed. They would come in on one instrument at the rate of forty words a minute, and would be ground out of our instrument at the rate of twenty-five. Then weren't we proud! Our copy used to be so clean and beautiful that we hung it up on exhibition; and our manager used to come and gaze at it silently with a puzzled expression. He could not understand it, neither could any of the other operators; for we used to hide my impromptu automatic recorder when our toil was over. But the crash came when there was a big night's work—a presidential vote, I think it was—and copy kept pouring in at the top rate of speed until we fell an

hour and a half or two hours behind. The newspapers sent in frantic complaints, an investigation was made, and our little scheme was discovered. We couldn't use it any more."

His fortunes rose and fell, for, although he was now becoming a very expert operator, taking messages with greater and greater speed, he would continue to stray into new fields of experiment. When he started to work in the Western Union office in Memphis, which was soon after the end of the Civil War, he found that all messages that were sent from New Orleans to New York had to be received at Memphis, sent on from there to Louisville, taken again, and so forwarded by half a dozen relays to New York. Many errors might creep in by such a system. To cure this he devised an automatic repeater, which could be attached to the line at Memphis, and would of its own accord send the message on. In this way the signals could go directly from New Orleans to New York. The device worked, and was highly praised in the local newspapers. But it happened that the manager of the office had a relative who was just completing a similar instrument, and Edison had forestalled him. Consequently he found himself discharged. He got a railroad pass as far as Decatur, and walked a hundred and fifty miles from there to Nashville. So by alternate riding and walking he finally reached Louisville. A little later he was offered a place in the Boston office.

He had plenty of nerve, and was not at all put out at the amusement of the other men when he walked into the Boston office, clad in an old and shapeless linen

duster. "Here I am," he announced to the superintendent. "And who are you?" he was asked. "Tom Edison. I was told to report here."

The superintendent sent him to the operating-room. Shortly after a New York telegrapher, famed for his speed, called up. Every one else was busy, and Edison was told to take his message. He sat down, and for four and a half hours wrote the messages, numbering the pages and throwing them on the floor for the office boy to gather up. As time went on the messages came with such lightning speed that the whole force gathered about to see the new man work. They had never seen such quickness. At the end of the last message came the words, "Who the devil are you?" "Tom Edison," the operator ticked back. "You are the first man in the country," wired the man in New York, "that could ever take me at my fastest, and the only one who could ever sit at the other end of my wire for more than two hours and a half. I'm proud to know you."

This story may be legendary, but it is known to be a fact that Edison was at this time the fastest operator in the employ of the Western Union, and that he could take the messages sent him with a careless ease which amounted almost to indifference. He had also cultivated an unusually clear handwriting, which was of great help in writing out the messages.

As soon as he was settled at the Boston office he opened a small workshop, where he might try to complete some of the many devices he had in mind. He took out his first patent in 1868, when he was twenty-

one years old, and it was obtained for what he called an electrical vote recorder. This was intended for use in Congress and the State Legislatures, and to take the place of the slow process of calling the roll on any vote. It was worked somewhat on the plan of the hotel indicator. The voter, sitting at his desk, would press one button if he wanted to vote "aye," and another if he wanted to vote "no." His vote was then recorded on a dial by the Speaker's desk, and as soon as each member had pressed one or the other button the total votes on each side could be known. The machine worked perfectly, and Edison took it to Washington in high hopes of having it adopted by Congress. The chairman to whom he was referred examined it carefully. Then he said, "Young man, it works all right and couldn't be better. With an instrument like that it would be difficult to monkey with the vote if you wanted to. But it won't do. In fact, it's the last thing on earth that we want here. Filibustering and delay in the counting of the votes are often the only means we have of defeating bad legislation. So, though I admire your genius and the spirit which prompted you to invent so excellent a machine, we shan't require it here. Take the thing away."

"Of course I was very sorry," said Edison, in speaking of this interview later, "for I had banked on that machine bringing me in money. But it was a lesson to me. There and then I made a vow that I would never invent anything which was not wanted, or which was not necessary to the community at large. And so far I believe I have kept that vow."

It was very evident there was a keen-witted man at work in the Boston office. The operators there had been much annoyed by an army of cockroaches that used to march across the table where they put their lunches and make a raid on the sandwiches and pies. One day Edison appeared with some tin-foil and four or five yards of fine wire. He unrolled the tin-foil, and, cutting two narrow strips from the long sheet, he stretched them around the table, keeping them near together, but not touching, and fastening them with small tacks. Then he connected the ribbons of foil with two batteries.

The leaders of the cockroach army arrived. The advance guard got his fore-creepers over the first ribbon safely, but as soon as they touched the parallel ribbon over he fell. In a very short time the invading army had met its Waterloo, and the lunches were safe from any further attack.

At another time the tin dipper that hung by the tank of drinking-water temporarily disappeared. When it was returned Edison put up a sign, reading, "Please return this dipper." He also connected the nail on which the dipper hung with a wire attached to an electric battery. After that the dipper stayed in its place under penalty of a wrenched arm for moving it without first disconnecting the battery.

Edison had now determined to become an inventor, and as soon as he was able gave up his position in the Boston telegraph office, where his routine work took too much of his time, and went to New York to look for other opportunities. It happened that one day

soon after his arrival he was walking through Wall Street and was attracted to the office of the Law Gold Indicator. The indicators or stock-tickers of this company were a new device, and were distributed through most of the large brokerage houses of the city. On the morning when Edison casually looked in, the machines had stopped work, no one could find out what was the matter, and the brokers were much disturbed. Edison watched Mr. Law and his workmen searching for the trouble. Then he said that he thought he could fix the machines. Mr. Law told him to try. He removed a loose contact spring that had fallen between the wheels, and immediately the tickers began to work again. The other workmen looked foolish, and Mr. Law asked the newcomer to step into his private office. At the end of the interview the owner had offered Edison the position of manager at a salary of three hundred dollars a month, and Edison had accepted.

He determined to improve this stock-indicator, and set to work at once. Soon he had evolved a number of important additions. The president of the company sent for him and asked how much he would take for these improvements. The inventor said that he would leave that to the president. Forty thousand dollars was named and accepted. Edison opened a bank account, and gave more time to working in his own laboratory. He had got well started up the rungs of the ladder he planned to climb.

His work lay along the lines of the telegraph, and he was anxious to win the support of the Western

Union for his new ideas. His chance came when there was a breakdown of the lines between New York and Albany. He went to the Western Union president, who had already heard of him, and said, "If I locate this trouble within two or three hours, will you take up my inventions and give them honest consideration?" The president answered, "I'll consider your inventions if you get us out of this fix within two days." Edison rushed forthwith to the main office. There he called up Pittsburg and asked for their best operator. When he had him he told him to call up the best man at Albany, and get him to telegraph down the line to New York as far as he could, and report back to him. Inside of an hour he received the message, "I can telegraph all right down to within two miles of Poughkeepsie, and there is trouble with the wire there." Edison went back to the president and told him that if he would send a repair train to Poughkeepsie they would find a break two miles the other side of the city and could have it repaired that afternoon. They followed his directions, and communication was restored before night. After that the Western Union officials gave the most careful consideration to every new invention that Edison brought them.

As soon as he had money in bank Edison carried out a plan he had long had in mind. He gave up his workshop in New York and opened a factory and experimenting shop in Newark, New Jersey, where he would have plenty of room for himself and his assistants. He began by manufacturing his improved "stock-

tickers," and he met with very considerable success. But he felt that manufacturing was not his forte. He said of this venture later, "I was a poor manufacturer, because I could not let well enough alone. My first impulse upon taking any apparatus into my hand, from an egg-beater to an electric motor, is to seek a way of improving it. Therefore, as soon as I have finished a machine I am anxious to take it apart again in order to make an experiment. That is a costly mania for a manufacturer."

In his Newark shop Edison now turned his attention to improvements on the telegraph. His first important invention was the duplex, by which two messages could be sent over the same wire in opposite directions at the same time without any confusion or obstruction to each other. This doubled the capacity of the single wire. Later he decided to carry this system farther, and perfected the quadruplex device. By this two messages could be sent simultaneously in each direction, and two sending and two receiving operators were employed at each end of a single wire. The principle involved was that of working with two electric currents that differ from each other in strength or nature, and which only affect receiving instruments specially adapted to take such currents, and no others. This invention changed a hundred thousand miles of wire into four hundred thousand, and saved the Western Union untold millions of dollars which would otherwise have had to be expended for new wires and repairs to the old ones.

Along somewhat similar lines Edison perfected an

automatic telegraph, an harmonic multiplex telegraph, and an autographic telegraph. The harmonic multiplex used tuning-forks to separate the several different messages sent at the same time, and the autographic telegraph allowed of the transmission of an exact reproduction of a message written by the sender in one place and received in another. And in addition to all these leading inventions he was continually improving on the main system, and his improvements were rapidly bought and taken over by the Western Union Company.

In almost as many diverse ways Edison improved upon the telephone. He had left his factory in Newark in charge of a capable superintendent, and moved his own laboratories to Menlo Park, a quiet place about twenty-five miles from Newark. His striking discoveries soon earned for him the nickname of "The Wizard of Menlo Park." Here he experimented with the new apparatus known as the telephone. He said of his own connection with it, "When I struck the telephone business the Bell people had no transmitter, but were talking into the magneto receiver. You never heard such a noise and buzzing as there was in that old machine! I went to work and monkeyed around, and finally struck the notion of the lampblack button. The Western Union Telegraph Company thought this was a first-rate scheme, and bought the thing out, but afterward they consolidated, and I quit the telephone business." As a matter of fact Edison has done a great deal of other work besides inventing his carbon transmitter in the telephone field, and the

Patent Office is well stocked with applications he has sent them for receivers and transmitters of different designs.

Edison has himself told of the main incidents in his perfection of the electric light. In the *Electrical Review* he said, "In 1878 I went down to see Professor Barker, at Philadelphia, and he showed me an arc lamp—the first I had seen. Then a little later I saw another—I think it was one of Brush's make—and the whole outfit, engine, dynamo, and one or two lamps, was traveling around the country with a circus. At that time Wallace and Moses G. Farmer had succeeded in getting ten or fifteen lamps to burn together in a series, which was considered a very wonderful thing. It happened that at the time I was more or less at leisure, because I had just finished working on the carbon-button telephone, and this electric-light idea took possession of me. It was easy to see what the thing needed: it wanted to be subdivided. The light was too bright and too big. What we wished for was little lights, and a distribution of them to people's houses in a manner similar to gas. Grovernor P. Lowry thought that perhaps I could succeed in solving the problem, and he raised a little money and formed the Edison Electric Light Company. The way we worked was that I got a certain sum of money a week and employed a certain number of men, and we went ahead to see what we could do.

"We soon saw that the subdivision never could be accomplished unless each light was independent of every other. Now it was plain enough that they could

not burn in series. Hence they must burn in multiple arc. It was with this conviction that I started. I was fired with the idea of the incandescent lamp as opposed to the arc lamp, so I went to work and got some very fine platinum wire drawn. Experiment with this, however, resulted in failure, and then we tried mixing in with the platinum about ten per cent. of iridium, but we could not force that high enough without melting it. After that came a lot of experimenting—covering the wire with oxide of cerium and a number of other things.

"Then I got a great idea. I took a cylinder of zirconia and wound about a hundred feet of the fine platinum wire on it coated with magnesia from the syrupy acetate. What I was after was getting a high-resistance lamp, and I made one that way that worked up to forty ohms. But the oxide developed the phenomena now familiar to electricians, and the lamp short-circuited itself. After that we went fishing around and trying all sorts of shapes and things to make a filament that would stand. We tried silicon and boron, and a lot of things that I have forgotten now. The funny part of it was that I never thought in those days that a carbon filament would answer, because a fine hair of carbon was so sensitive to oxidation. Finally, I thought I would try it because we had got very high vacua and good conditions for it.

"Well, we sent out and bought some cotton thread, carbonized it, and made the first filament. We had already managed to get pretty high vacua, and we thought, maybe, the filament would be stable. We

built the lamp and turned on the current. It lit up, and in the first few breathless minutes we measured its resistance quickly and found it was 275 ohms—all we wanted. Then we sat down and looked at that lamp. We wanted to see how long it would burn. The problem was solved—if the filament would last. The day was—let me see—October 21, 1879. We sat and looked, and the lamp continued to burn, and the longer it burned the more fascinated we were. None of us could go to bed, and there was no sleep for any of us for forty hours. We sat and just watched it with anxiety growing into elation. It lasted about forty-five hours, and then I said, 'If it will burn that number of hours now, I know I can make it burn a hundred.' We saw that carbon was what we wanted, and the next question was what kind of carbon. I began to try various things, and finally I carbonized a strip of bamboo from a Japanese fan, and saw that I was on the right track. But we had a rare hunt finding the real thing. I sent a schoolmaster to Sumatra and another fellow up the Amazon, while William H. Moore, one of my associates, went to Japan and got what we wanted there. We made a contract with an old Jap to supply us with the proper fibre, and that man went to work and cultivated and cross-fertilized bamboo until he got exactly the quality we required."

This is the inventor's own statement, but it gives a very meagre notion of the many months' experimenting in his workshop while he hunted for a suitable filament for his electric light.

As he said, after he had first seen the Brush light,

and studied it, he decided that the main problem was one of distribution, and thereupon considered whether he should use the incandescent or the voltaic arc in the system he was planning. At last he decided in favor of the incandescent light.

Then began the long months of testing platinum wire. He wanted to find some way of preventing this hardest of all metals from melting when the full force of the electric current was turned into it. He worked out several devices to keep the platinum from fusing, an automatic lever to regulate the electric current when the platinum was near the melting-point, and a diaphragm with the same object; but all of them had to be discarded. Although he was still searching for the right clue he seems to have had no doubt of his final success. He said at this time, "There is no difficulty about dividing up the current and using small quantities at different points. The trouble is in finding a candle that will give a pleasant light, not too intense, which can be turned off and on as easily as gas. Such a candle cannot be made from carbon points, which waste away, and must be regulated constantly while they do last. Some composition must be discovered which will be luminous when charged with electricity and that will not wear away. Platinum wire gives a good light when a certain quantity of electricity is passed through it. If the current is made too strong, however, the wire will melt. I want to get something better."

It was generally known that Edison was working along this line. An English paper, commenting on the matter, said, "The weak point of the lamp is this,

that in order to be luminous, platinum must be heated almost to the point of melting. With a slight increase in the current, the lamp melts in the twinkling of an eye, and in practice the regulator is found to short-circuit the current too late to prevent the damage. It is this difficulty which must be overcome. Can it be done?"

After long study Edison concluded that pure platinum was not suited to successful electric lighting. Then he incorporated with it another material of a non-conducting nature, with the result that when the electric current was turned on one material became incandescent and the other luminous. This gave a clear, but not a permanent, light. He tried many different combinations, and experimented month after month, but none of his trials produced the result he wanted, and at last he concluded that he was on the wrong track, and that neither platinum nor any other metal would give the right light.

There is something very dramatic about his real discovery. He was sitting in his laboratory one evening, when his right hand happened to touch a small pile of lampblack and tar that his assistants had been using in working on a telephone transmitter. He picked up a little of it, and began to roll it between his finger and thumb. He was thinking of other things, and he rolled the mixture absent-mindedly for some time, until he had formed a thin thread that looked something like a piece of wire. Glancing at it, he fell to wondering how it would serve as a filament for his light. It was carbon, and might be able to stand a stronger current than plat-

inum. He rolled some more of the mixture, and decided to try it.

His experiments had already resulted in the production of an almost absolute vacuum, only one-millionth part of an atmosphere being left in the tube. Such a vacuum had never been obtained before. With his assistant, Charles Bachelor, he put a thread of the lampblack and tar in a bulb, exhausted the air, and turned on the current. There was an intense glow of light; but it did not last, the carbon soon burned out. Therefore he started to study the reason why the carbon had failed to withstand the electric current. His conclusion was that it was impossible to get the air out of the lampblack. Besides that the thread became so brittle that the slightest shock to the lamp broke it. But he felt certain now that a carbon filament, made of something other than tar and lampblack, was what he wanted.

He next sent a boy to buy a reel of cotton, and told his assistants he was going to see what a carbonized thread would do. They looked doubtful, but began the experiment. A short piece of the thread was bent in the form of a hairpin, laid in a nickel mould and securely clamped, and then put in a muffle furnace, where it was kept for five hours. Then it was taken out and allowed to cool. The mould was opened and the carbonized thread removed. It instantly broke. Another thread was put through the same process. As soon as it was taken from the mould it broke. Then a battle began that lasted for two days and two nights, the object of which was to get a carbonized thread that would not break. Edison wanted that thread because

it contained no air, and might stand a greater current than the lampblack. Finally they took from the mould an unbroken thread, but as they tried to fasten it to the conducting wire it broke into pieces. Only on the night of the third day of their work, in all which time they had taken no rest, did they get a thread safely into the lamp, exhaust the air, and turn on the current. A clear, soft light resulted, and they knew that they had solved the problem of the incandescent light.

Edison and Bachelor watched that light for hours. They had turned on a small current at the start, to test the strength of the filament, but as it stood it, they turned on a greater and greater current until the thread was bearing a heat that would have instantly melted the platinum wire. The cotton thread glowed for forty-five hours, and then suddenly went out. The two watchers ended their long vigil, exhausted, but very happy. They knew that they had found the light that was to be the main illumination for the world.

But Edison realized that he had not yet found the ideal filament. The cotton thread had only lasted forty-five hours, and he wanted one that would burn for a hundred hours or longer. He wanted a more homogeneous material than thread, and he began to try carbonizing everything he could lay his hands on, straw, paper, cardboard, splinters of wood. He found that the cardboard stood the current better than the cotton thread, but even that did not burn long enough. Then he happened upon a bamboo fan, tore off the rim, and tried that. It made a filament that gave better results than any of the others.

Now he began his exhaustive study of bamboo. He learned that there were more than twelve hundred known varieties of bamboo. He wanted to find the most homogeneous variety. He sent out a number of men to hunt this bamboo, and it is said that the search cost nearly $100,000. Six thousand specimens of bamboo were carbonized, and he found three kinds of bamboo and one of cane that gave almost the result he wanted. All of these grew in a region near the Amazon, and were hard to get on account of malarial conditions. But at last he discovered the bamboo species that suited him, and he was ready to give his new light to the world.

The world was waiting for it. Scientists and the press reported his invention everywhere. He hung a row of lamps from the trees at Menlo Park, and the thousands who came to see them wondered when they found they could burn day and night for longer than a week. The lamps were small and finely made, they could be lighted or extinguished by simply pressing a button, and the cost of making them was slight. The last doubters surrendered, and admitted that Edison had given the world a new light, and one which was not simply a scientific marvel, but was eminently practical and useful.

But Edison is never satisfied with what he has done in any line; he must try to increase the service each invention gives. Therefore he now conceived the idea of having a central station from which every one might obtain electric light as they had formerly obtained gas. There were gigantic difficulties in the way of such an

undertaking. Hardly any one outside of Edison's own laboratory knew anything about electric lighting, and there were only a few of them who could be trusted to put a carbon filament in an exhausted globe.

He went about this new development in the most methodical way. He got an insurance map of New York City, and studied the business section from Wall to Canal Streets and from Broadway over to the East River. He knew where every elevator shaft and boiler and fire-wall was, and also how much gas each resident used and what he paid for it. This last he learned by hiring men to walk through the district at two o'clock in the afternoon and note how many gas lights were burning, then to make the rounds again at three, and again at four, and so on into the hours of the next morning.

With the field carefully examined he formed the New York Edison Illuminating Company, and had his assistants take charge of factories for making lamps, dynamos, sockets, and the other parts necessary for his lights. It was very difficult to get the land he wanted for his central station, but he finally bought two old buildings on Pearl Street for $150,000. He had little room space and he wanted to get a big output of electricity. So he decided to get a high-speed engine. They were practically unknown then, and when he went to an engine builder and said that he wanted a 150 horse-power engine that would run 700 revolutions per minute he was told it was impossible. But he found a man to build one for him, and set it up in the shop at Menlo Park. The shop was built on a shale

hill, and when the engine was started the whole hill shook with the high speed revolutions. After some experimenting and changing they got the power that Edison wanted, and he ordered six more engines like the first.

In the meantime workmen had been busy digging ditches and laying mains through the district that Edison intended to light. The engines were set up in the central station and tried out. Then the troubles began. The engines would not run evenly, one would stop and another go dashing on at a tremendous speed. Edison tried a dozen different plans before he brought anything like order out of that engine chaos. Finally he had some engines built to run at 350 revolutions and give 175 horse-power, and these proved what was required. September 4, 1882, he turned the current on to the mains for the needed light service, and it stayed on with only one short stoppage for eight years.

In this way Edison invented the electric light and evolved the central station that should provide the current wherever it was needed. At the same time he had worked out countless adjuncts to it, the use of the fine copper thread to serve as a fuse wire and prevent short-circuiting, the meter, consisting of a small glass cell, containing a solution in which two plates of zinc are placed, and which shows how much current is supplied, the weighing voltameter, and other instruments for estimating the current, and improvements on the motors and engines. There was no field remotely connected with electric lighting that he did not enter. Yet as soon as the invention was actually before the

Edison and the Early Phonograph

world business competitors sprang up on every hand. There was more litigation over this than over any other of Edison's inventions. "I fought for the lamp for fourteen years," he said, "and when I finally won my rights there were but three years of the allotted seventeen left for my patent to live. Now it has become the property of anybody and everybody."

Edison had always wanted a model laboratory, one that should be fitted with the most perfect instruments obtainable, and supplied with all the materials he could possibly require in any of his extraordinary experiments. In 1886 he bought a house in Llewellyn Park, New Jersey, and near the house ten acres of land, on which he built the laboratory of his dreams. Here he had a large force of skilled workmen constantly engaged in developing his ideas, and the expenses were paid by the many commercial companies in which he was interested, and which profited by the improvements he was continually making in their machinery.

Many volumes might be written to tell of the "Wizard's" achievements. There has been no inventor who has covered such a field, and each step he takes opens new and fascinating vistas to his ever-inquiring eyes. Electricity is always his main study, and electricity he expects in time will revolutionize modern life by making heat, power, and light practically as cheap as air. But other subjects have concerned him almost as much. He ranges from new processes for making guns to the supplying of ready-made houses built of cement. Everything interests him, every object tempts him to try his hand at improving on it.

The phonograph is his achievement, and the practical development of the kinetoscope. He has built electric locomotives and run them, he has made many discoveries in regard to platinum. His better known patents include developments of the electric lamp, the telephone, storage-batteries, ore-milling machinery, typewriters, electric pens, vocal engines, addressing machines, cast-iron furniture, wire-drawing, methods of preserving fruit, moving-picture machines, compressed-air machines, and the manufacture of plate glass. He took out a patent covering wireless telegraphy in 1891, but other matters were then absorbing his attention, and he was quite willing to yield that field to the brilliant Italian, Marconi. He feels no jealousy for other inventors. He knows how vast the field is, and how many paths constantly beckon him.

It is doubtless true that the great inventors are born and not made, but many of them seem, nevertheless, to have drifted into the work that gave them fame, or to have hit by chance on their compelling idea. It was not so with Edison. He was beyond any doubt born an inventor. With him to see was to ask the question why, and to ask that question was to start his thoughts on the train that was to bring him to the answer.

XV

MARCONI AND THE WIRELESS TELEGRAPH

1874–

AT first sight the wireless telegraph seems the most wonderful of all inventions and discoveries, the one that is least easy to understand, and that most nearly approaches that magic which is above all nature's laws. Even if we do come to understand it it loses nothing of its wonder, and the last impression is very like the first. We can understand how an electric current travels through a wire, even if we cannot understand electricity, but how that current can travel through limitless space and yet reach its destination strains the imagination. Yet wireless telegraphy is not a matter of the imagination, but of exact, demonstrable science.

On December 12, 1901, a quiet, dark-skinned young man sat, about noontime, in a room of the old barracks building on Signal Hill, near St. John's, Newfoundland. On the table in front of him was a mechanical apparatus, with an ordinary telephone receiver at its side. The window was partly open, and a wire led from the machine on the table through the window to a gigantic kite that a high wind kept flying fully 400 feet above the room. The young man picked up the

receiver, and held it to his ear for a long time. His face showed no sign of excitement, though an assistant, standing near him, could barely keep still. Then, suddenly, came the sharp click of the "tapper" as it struck the "coherer." That meant that something was coming. The young man listened a few minutes, and then handed the receiver to his assistant. "See if you can hear anything, Mr. Kemp," said he. The other man took the receiver, and a moment later his ear caught the sound of three little clicks, faint, but distinct and unmistakable, the three dots of the letter S in the Morse Code. Those clicks had been sent from Poldhu, on the Cornish coast of England, and they had traveled through air across the Atlantic Ocean without any wire to guide them. That was one of the great moments of history. The young man at the table was Guglielmo Marconi, an Italian.

We know that it is no injustice to a great inventor to say that other men had imagined what he achieved, and had earlier tried to prove their theories. It takes nothing from the glory of that other great Italian, Columbus, to recall that other sailors had planned to cross the sea to the west of Europe and that some had tried it. So James Clerk-Maxwell had proved by mathematics the electro-magnetic theory of light in 1864, and Heinrich Hertz had demonstrated in 1888 by actual experiment that electric waves exist in the free ether, and Edison had for a time worked on the problem of a wireless telegraph. Marconi devised the last link that made the wonder possible, and caught the first click that came across the sea, and to him belong the palms.

Judge Townsend, in deciding a suit in a United States court in 1905, declared, "It would seem, therefore, to be a sufficient answer to the attempts to belittle Marconi's great invention that, with the whole scientific world awakened by the disclosures of Hertz in 1887 to the new and undeveloped possibilities of electric waves, nine years elapsed without a single practical or commercially successful result, and Marconi was the first to describe and the first to achieve the transmission of definite intelligible signals by means of these Hertzian waves."

Marconi was born at Villa Griffone, near Bologna, in 1874, so that he was under thirty when he caught that first transatlantic message. He studied at Leghorn under Professor Rosa, and later at the University of Bologna with Professor Righi. He was always absorbed in science, and experimented, holiday after holiday, on his father's estate. He was precocious to an extraordinary degree, for in 1895, when only twenty-one, he had produced a wireless transmitting apparatus that he patented in Italy. Within a year he had taken out patents in England and in other European countries, and had proposed a wireless telegraph system to the English Post-Office Department. That Department, through Sir William Henry Preece, Engineer-in-Chief of Telegraphs, took up the subject, and reported very favorably on the Marconi System. Marconi himself, at the House of Commons, telegraphed by wireless across the Thames, a distance of 250 yards. In June, 1897, he sent a message nine miles, in July twelve miles, and in 1898 he succeeded in sending one across the English

Channel to France, thirty-two miles. In 1901 he covered a space of 3,000 miles.

Let us now see what it was that Marconi had actually done.

Wireless signals are in reality wave motions in the magnetic forces of the earth, or, in other words, disturbances of those forces. They are sent out through this magnetic field, and follow the earth's curvature, in the same way that tidal waves follow the ocean's surface. Everywhere about us there is a sea of what science calls the ether, and the ether is constantly in a state of turmoil, because it is the medium through which energy, radiating from the sun, is carried to the earth and other planets. This energy is transmitted through the free ether in waves, which are known as electro-magnetic waves. It was this fact that Professor Hertz discovered, and the waves are sometimes called the Hertzian waves. Light is one variety of wave motion, and heat another. The ether must be distinguished from the air, for science means by it a medium which exists everywhere and is to be regarded as permeating all space and all matter. The ether exists in a vacuum, for, although all the air may have been withdrawn, an object placed in a vacuum can still be seen from outside, and hence the wave motions of light are traveling through a space devoid of air.

Professor Hertz proved in 1888 that a spark, or disruptive discharge of electricity, caused electro-magnetic waves to radiate away in all directions through the ether. The waves acted exactly like ripples that radiate from a stone when it strikes the water. These

Hertzian waves were found to travel with the same velocity as light, and would circle the world eight times in a second. As soon as the existence of these waves was known many scientists began to consider whether they could not be used for telegraphy. But the problem was a very difficult one. The questions were how to transmit the energy to a distance, and how to make a receiver that should be sensitive enough to be affected by it.

Let us picture a body of still water with a twig floating upon its surface. If a stone is thrown into the water ripples radiate in all directions, these waves becoming weaker as the circles they form become larger, or in other words as they grow more distant from the point where the stone struck the water. When the waves reach the floating twig they will move it, and when they cease the twig will be motionless again. Should there be grasses or rocks protruding up from the water the motion given to the twig by the waves would be lessened, or distorted, or changed in many ways, depending on the intervening object. Whether the waves will actually impart motion to the twig will depend on the force by which these waves were started and upon the lightness of the twig, or its sensitiveness to the ripples as they radiate. If the water were disturbed by some other force than the stone the twig would be moved by that other force, and the observer could not tell from what direction the motion had come, or how it had been caused. Applying this to wireless telegraphy one may say that a device must be used that will send out waves of a certain length, and that

the receiver must be constructed so that it will respond only to waves of the length sent by that transmitter.

There must therefore be accurate tuning of the two instruments. Let a weight be fastened at the end of a spiral spring and then be struck. The weight will oscillate at a uniform rate, or so many times a minute. If this be held so that it strikes the water the movement of the spring will create a certain number of waves a minute. If now a second weight, attached to a second spring, be hung down into the water, the waves caused by the first will reach the second, and if the springs be alike the movements or oscillations will correspond. But if the springs were not alike, or if, in other words, the two instruments were not in tune, the wave motions would not be received and copied accurately. Therefore in wireless telegraphy the instrument that is to impart the motion to the electro-magnetic waves that fill the ether must be tuned in accord with the instrument that is to receive the motion of those waves.

The sending of the wireless message requires a source of production of the electro-magnetic waves. This is obtained by what is known as capacity, or in other words, the power that is possessed by any metal surface to retain a charge of electricity, and by inductance, procured when a constantly changing current is sent through a coil of wire. This capacity and inductance must be adjusted to give exactly the same frequency of motion to the waves, or the same oscillations, if the receiver that is tuned to vibrate to those waves is to receive that message accurately. The receiving station must have the means to intercept the waves, and then

transform them again into electrical oscillations that shall correspond to those sent out from the transmitting station.

As early as 1844 Samuel F. B. Morse had succeeded in telegraphing without wires under the Susquehanna River, and in 1854 James Bowman Lindsay, a Scotchman, had sent a message a distance of two miles through water without wires. Sir William Henry Preece, by using an induced current, had telegraphed several miles without a connecting wire. But the discoveries made in regard to the Hertzian waves placed the subject on a different footing, and the possibility of an actual usable wireless telegraph was now looked at from a new view-point.

Professor Hertz had used a simple form of apparatus to obtain his free ether waves. A loop of wire, with the ends almost touching each other, had been his receiver, or detector. When he set his generator, or instrument to create the oscillations, in operation, and held the detector near it, he could see very minute electric sparks passing between the ends of the loop of wire. This proved the existence of the electro-magnetic waves.

In 1890 Professor Eduard Branly found that loose metallic filings became good conductors of electricity when there were electric oscillations at hand. He demonstrated this by placing the filings between metal plugs in a glass tube, and connecting this in circuit with a battery and electric indicator. Professor Oliver Lodge named this device of Branly's a "coherer," and when he found that it was more sensitive than the Hertz

detector he combined it with the Hertz oscillator. This was in 1894, and the combination of oscillator and coherer actually formed the first real wireless set.

Wireless stations on shore are marked by very tall masts, which support a single wire, or a set of wires, which are known as the *antenna*. The antenna has electrical capacity, and when it is connected with the other apparatus needful to produce the oscillations it disturbs the earth's magnetic field. For temporary service, as in the case of military operations, the antenna is frequently attached to captive balloons or kites, and so suspended high in air. On ships the antenna is fastened to the masts. The step that led to this addition was taken by Count Popoff in 1895, when he attached a vertical wire to one side of the coherer of the receiver of Professor Lodge, and connected the other side with the ground. He used this to learn the approach of thunder-storms.

With a knowledge of electro-magnetic waves, with a high-power oscillator, and a sensitive coherer, it remained for Marconi to connect an antenna to the transmitter, and thus secure a wide and practicable working field for the sending and receiving of his messages. This he did in 1896, and it was this addition that made the wireless telegraph of real use to men. Improvements in the transmitter and receiver have constantly increased the power of the invention, and have gradually allowed him to employ it over greater and greater distances.

With Marconi's successful demonstrations of wireless in England its use at once began. The Trinity House

Wireless Station in New York City, Showing the Antenna

installed a station at the East Goodwin Lighthouse, which communicated with shore and proved of the greatest value in preventing shipwrecks. The Marconi Wireless Telegraph Company was organized in 1897, and made agreements to erect coast stations for the Italian, Canadian, and Newfoundland governments, and for Lloyd's. The great shipping lines established wireless stations on their vessels, and the antenna were soon to be seen on points of vantage along every coast. On December 12, 1901, Marconi in Newfoundland caught the message sent from Cornwall; on January 19, 1903, President Roosevelt sent the first "official" wireless message across the Atlantic to Edward VII, and in October, 1905, a message was sent from England across the mountains, valleys and cities of Europe to the battle-ship *Renown*, stationed at the entrance to the Suez Canal.

The system of operating wireless telegraphy is in some respects similar to that of the ordinary telegraph. The Morse Code is largely used in America, and a modification of it, called the Continental Code, in Europe. When the wireless operator wishes to send a message to another station he "listens in," as it is called, by connecting his receiving apparatus with the adjacent antenna and the ground. He has the telephone receiver attached to his ears. Next he adjusts his receiving circuits for a number of wave lengths. If he catches no signals in his telephone receiver he understands that no messages are being sent within his area. Then he "throws in" the transmitting apparatus, which automatically disconnects the receiving

end. He gives the letters that stand for the station with which he wants to communicate, and adds the letters of his own station. He does this a number of times, to insure the other station picking up the call. Then he "listens in," and if he receives the clicks that show that the other station has heard him he is ready to establish regular telegraphic communication.

A number of distant stations may be sending messages simultaneously. In that case the operator tunes his instrument, or in other words adjusts his apparatus to suit the wave length of the station with which he wishes to communicate. In this way he "tunes out" the other messages, and receives only the one he wants. If, however, the stations that are sending simultaneously happen to be situated near together, as in the case of several vessels near a shore station, the operator is often unable to do this "tuning out," and must try to catch the message he wishes by the sound of the "spark" of the transmitting station, if he can in any way distinguish it from the "sparks" of the other messages.

There are several ways of determining when the two circuits are in tune. One is to insert a hot-wire current meter between the antenna and the inductance, which indicates the strength of the oscillatory current that has been established. A maximum reading can then be made by manipulating the flexible connections, and this will show whether the two circuits are in accord. The other method is by using a device that indicates the wave length. This measures the frequency of one circuit, and then the other circuit can be adjusted to

give a corresponding wave length. The larger the antenna the longer will be the wave length and the greater the power of the apparatus. It is usual to employ a short wave length for low-power, short-distance equipments, and a long wave length for the high-power, long-distance stations.

Wireless telegraphy has already proved itself of the greatest value on the ocean. It has sent news of storms and wrecks across tossing seas and brought rescue to scores of voyagers. Ships may now keep in constant communication with their offices on shore. The great lines send Marconigrams to each other in mid-ocean, and publish daily papers giving the latest news of the whole world. Greater distances have so far been covered over water than over land, but this branch of the service is being rapidly developed, and it must prove in time of the greatest value across deserts and wild countries, where a regular telegraph service would be impracticable. In such a country as Alaska, where there are constant heavy sleet and snow storms, the wireless should prove invaluable.

The telegraph and cable companies did their best to ignore the claims of the wireless systems, but they have been compelled to acknowledge them at last. Rival companies have sprung up, using slightly different varieties of apparatus. Each of the big companies that were ready to compete with the Marconi Company by 1906, the German Telefunken Company, the American National Electric Signaling Company, the American De Forest Company, and the British Lodge-Muirhead Wireless Syndicate, had certain peculiar advantages

over the others. The laws relating to the uses of wireless, and especially the rights of governments to the sole use of the systems in case of war, are in a confused condition, but eventually order must come from this chaos as it did in the history of the telephone and telegraph.

Wireless has brought the possibility of communication between any two individuals, no matter where they may be situated, within the realm of fact. A severing of communication with any part of the world will be impossible. Storms and earthquakes that destroy telegraph systems, enemies that cut submarine cables, cannot prevent the sending of Marconigrams. The African explorer and the Polar adventurer can each talk with his countrymen. The use of this agency is still in its earliest youth, but it has already done so much that it is impossible to say to what a stature it may grow. It should cut down the rates for using wire and cable systems, and ultimately place the means of communicating directly with any one on land or sea within the reach of every man. All the world's information will be at the instant disposal of whomsoever needs it, and all this is due to those electro-magnetic waves that permeate the ether, waiting to be put into service at the touch of man.

XVI

THE WRIGHTS AND THE AIRSHIP

Wilbur Wright 1867–
Orville Wright 1871–

MEN have always wanted to be able to fly. So long as there have been birds to watch, so long have men of speculative minds wondered at the secret of their flight. Early in recorded history men built ships to sail across the seas, but the problem of air navigation has always baffled them. The balloon came into being, but the balloon for years was only a toy, dependent on the wind's whim, and of the least possible service to men. The problem of aerial navigation was to master the currents of the air as the sailing-vessel and the steamship had overcome the waves and tides at sea.

The history of invention often shows that some great thinker, or school of thinkers, has stated a scientific conclusion that generations of later men have never dared to question. The laws of Aristotle in regard to falling bodies were never doubted until Galileo began to wonder if they could be true. Sir Isaac Newton had stated, and mathematical computations had proved his words, that a mechanical flying-machine was an impossibility. Any such machine must be heavier than the air it flew in. The weight of Newton's authority and the weight of figures were compelling facts, such as scientists had no mind to doubt. But in spite of

these facts men could see that birds flew, although they were often a thousand times heavier than the air they went through. And that sight kept men speculating, in spite of all the figures and scientific dicta of the ages.

It was known for centuries that if a kite was held in position by a string reaching to the ground the wind blowing against it would keep it supported in the air. Now if the kite, instead of being stationary in moving air, were to be moved constantly through quiet air it would also stay up. The motive power might be supplied by a motor and propellers, but in order to do away with the string which holds the kite in position the aeroplane, which is only a big kite in principle, must have some way of balancing itself so that it will stay in the proper position in the air.

A German engineer, Otto Lilienthal, made a study of the mechanics of birds' flights, and determined to learn their secret by actual trial. He built wings that were similar to those of the hawk and buzzard, the great soaring birds, and in 1891 he began to throw himself from the tops of hills, supported by these wings, and glided through the air into the valleys. In this way he learned new laws of flight, contradicting many theories of the scientists, and opening a new world of speculation. But in August, 1896, his wings broke in a sudden gust of wind, he fell fifty feet, and died of a broken back.

It was this problem of balancing that had cost Lilienthal his life. He had tried to balance himself by throwing his weight quickly from side to side as he held to his "gliding machine." His pupil, Percy S.

Pilcher, an Englishman, continued his experiments, trying the same method of balancing, but in September, 1899, his wings broke, and he met the same fate as his teacher. It seemed that men could not shift their weight quickly enough to meet the gusts of wind.

Meantime new theories of flight were being worked out in the United States. Professor S. P. Langley, of the Smithsonian Institution, had made experiments with plates of metal moved through the air at various rates of speed and at different angles, and had published his new conclusions in regard to the support the air would furnish flying-planes in 1891. In 1896 he built a small steam-aeroplane that flew a distance of three-quarters of a mile down the Potomac River. And in the same year Octave Chanute, of Chicago, with the aid of A. M. Herring, built a multiple-wing machine and tried it successfully on the banks of Lake Michigan. But the problem of balancing was not yet solved, and here Wilbur and Orville Wright entered upon the scene.

The Wrights' home was in Dayton, Ohio, and there they had spent their boyhood, in no way distinguished from their neighbors. Their father had been a teacher, an editor, and a bishop of the United Brethren Church. He had traveled a great deal, and was an unusually well-educated man. Their mother had been to college. Their two older brothers and their sister were college graduates, and the younger boys would have had the same education had their mother not died and they decided to stay at home and look after affairs for their father, who was often away. In telling the story of their invention in *The Century* for September, 1908, they

said, "Late in the autumn of 1878 our father came into the house one evening with some object concealed in his hands and, before we could see what it was, tossed it into the air. Instead of falling to the floor, as we expected, it flew across the room and struck the ceiling, where it fluttered a while and finally sank to the floor. It was a little toy known to scientists as a helicoptere, but which we, with sublime disregard for science, dubbed a 'bat.' . . . It lasted only a short time, but its memory was abiding." At that time Wilbur was eleven and Orville seven years old.

These two brothers, scientifically minded, started a bicycle shop, and bade fair to become ordinarily prosperous citizens of Dayton, much like their neighbors. They were, however, deeply interested in news from the world of science and invention, and when they read in 1896 that Lilienthal had been killed by a fall from his glider they began to wonder what were the real difficulties that must be overcome in flying. Further reading awakened a deep interest in the problem of the airship, and they worked upon it, at first as a scientific pastime, but soon in all seriousness. They built models in their workshop, and experimented with them. Then, in 1900, Wilbur wrote to his father that he was going on a holiday to a place in North Carolina called Kitty Hawk, to try a glider.

The Wrights realized in 1900 that the only problem to be solved was that of equilibrium. Men had made aeroplanes that would support them in motion, and also engines that were light enough to drive the planes and carry their own weight and that of the aviator. But

when the wind blew the aeroplane was as likely as not to capsize. Their study was how to keep the machine from turning over.

The air does not blow in regular currents. Instead, near the earth, it is continually tossing up and down, and often whirling about in rotary masses. There is constant atmospheric turmoil, and the question is how to maintain a balance in these currents that bear the machine. Put in technical form it is how to make the centre of gravity coincide with the centre of air-pressure.

The shifting of the air-currents means that the centre of air-pressure moves. The aeroplane is sailed at a slight angle to the direction in which it is heading, and the centre of air-pressure is on the forward surfaces of the machine. The wind strikes the front, but rarely touches the back of the plane, and so gains a great leverage that adds materially to its power to overturn the machine. As the wind veers continually it is easy to see the aviator's difficulty in keeping track of this centre of pressure.

Both Lilienthal and Chanute had tried to balance by shifting their weight, but this was extremely exhausting, and often could not be done in time to meet the changing currents. The Wrights realized that a more automatic method of meeting these changes must be found, and they worked it out by shifting the rudder and the surfaces of the airship as it met the air-currents.

The earlier aviators had found that two planes, or "double-deckers," gave the best results. The Wrights

adopted this type, believing that it was the strongest form, and could be made more compact and be more easily managed than the single plane, or the many-winged type. They built their gliding-machine of cloth and spruce and steel wire. But instead of the aviator hanging below the wings, as in the other planes, he lay flat across the centre of the lower wing. A horizontal rudder extended in front of the plane instead of behind it. This not only guided the flight of the machine, but counterbalanced the changes of the centre of air-pressure. To steer, the wings were moved by cords controlled by the aviator's body. They considered that the shiftings of the air were too rapid to be followed by conscious thought, and so their plan was to have a plane that would balance automatically, or by reflex action, as a bicycle is balanced.

Langley had adopted wings that slanted upward from the point at which they joined, copying the wings of a soaring buzzard. The Wrights doubted whether this was the best form for shifting weather, and built theirs more on the pattern of the gull's wings, curving slightly at the tips. They were made of cloth, arched over ribs to imitate the curved surfaces of bird's wings, and were fastened to two rectangular wooden frames, fixed one above the other by braces of wood and wire.

Their next step was to try to find some method by which they might keep their gliding-machine continuously in the air, so that they might gain an automatic balance. The old method of launching the plane from a hill gave little chance for a real test. Study taught them that birds are really aeroplanes, and that buzzards

and hawks and gulls stay in the air by balancing on or sliding down rising currents of air. They looked for a place where there should be winds of proper strength to balance their machine for a considerable time as it slid downward, and decided to make their experiments at Kitty Hawk, North Carolina, on the stretch of sand-dunes that divided Albemarle Sound from the Atlantic Ocean. They calculated that their gliding-machine, with 165 square feet of surface, should be held up by a wind blowing twenty-one miles an hour. The machine was to be raised like a kite, with men holding ropes fastened to the end of each wing. When the ropes were freed the aviator would glide slowly to the ground, having time to test the principle of equilibrium. This plan would also do away with the former need of carrying the plane up to the top of a hill before each flight.

They found in practice that their plan of raising the plane like a kite was impracticable, and that the wind was not strong enough to support it at a proper angle. They had to glide from hills as others had done, but they discovered that their theory of steering and balancing by automatically shifting surfaces worked very much better than the old method of shifting the aviator's weight.

In 1901 and 1902 the Wrights continued their gliding experiments at Kitty Hawk. Their new machines were much larger, and they added a vertical tail in order to secure better lateral balance. Sometimes the wind was strong enough to lift the aviator above the point from which he had started and hold him motion-

less in the air for half a minute. They made new tables of calculation for aerial flight, and found that a wind of eighteen miles an hour would keep their plane and its operator in the air.

Their next step was to place a gas-engine on their aeroplane and attempt actual mechanical flight. After many experiments they succeeded, and on December 17, 1903, the first airship made four flights at Kitty Hawk. In the longest flight it stayed in the air fifty-nine seconds, and flew against a twenty-mile wind. It weighed, with the aviator, about 745 pounds, and was propelled by a gas-engine weighing 240 pounds, and having twelve or thirteen horse-power. That test assured them that mechanical flight was possible.

The Wrights had now solved the real problem of aviation, equilibrium. They were ready to try mechanical flights in places where the wind-conditions were less favorable than at Kitty Hawk. They secured a swampy meadow eight miles east of Dayton, and, using that secrecy which they have always believed was necessary to the protection of their interests, began to fly there. Their airship flew well in a straight course, but there was difficulty in turning corners. Sometimes it could be done, but occasionally the plane would lose its balance as it turned, and have to be brought to the ground. In time they remedied this, and on September 20, 1904, they were able to make a complete circle. Later in that same year they made two flights of three miles each around a circular course.

The Wrights' system of balance, the great original feature of their invention, is attained by what is called

the warping of the wings. When they are flying, and some cause, such as a change in their position, or a sudden gust of wind, makes the airship tip, a lever is moved, and the two planes warp down on the end that is canting toward the earth. Simultaneously the two opposite ends of the planes warp up. The lower ends at once gain greater lifting power, the upper ends less. Therefore the airship stops tilting and comes back to an even flight. The lever is instantly moved to keep the machine from tipping to the other side.

When the airship came to turn a corner it was apt to "skid." It slid from its balance, owing to the change in its course against the currents of air. The Wrights overcame this by having the planes of their machine warp at the same instant that the rudder shifts the course, by this raising one wing and lowering the other, so that the aeroplane cants over and makes the circle leaning against the wind, on the same principle that a bicycler takes a curve on an angle instead of riding upright. The problems of balance and of turning corners were therefore both met and solved by warping the planes to meet the conditions of the airship's contact with the wind.

One of the chief reasons for the Wrights' success was that they had studied their subject long and faithfully before they tried to fly. They had worked with their gliders several years, and had made new calculations of the changing angles and currents of air. They had been in no hurry, and when they built their first real airship they made use of all the principles of aerodynamics that they had discovered. They knew

that their machine would fly before they tried it, because they knew exactly what its various surfaces would do in the air. The propeller was the only part of their airship they had not studied when they began to build. When they found that they could not use the figures that had governed the construction of marine propellers they set to work to solve this problem in the same thoroughgoing way. They mastered it, and their success with their propeller is the feature of their airship in which they take the greatest pride.

The first official statement of their progress in flying was made in letters of the Wrights in the *Aerophile* in 1905, and to the Aero Club of America in 1906. These declared that they had begun actual flight with a motor-driven aeroplane on December 17, 1903, had then spent the year 1904 in experimenting with flights in circular courses, and had so learned the proper methods of control of the planes by 1905 that they had at last made continuous flights of eleven, twelve, fifteen, twenty, twenty-one, and twenty-four miles, at a speed of about thirty-eight miles an hour, and had been able to alight safely in each instance, ready to fly again as soon as their fuel was replenished.

Until that date the inventors had been singularly successful in keeping their experiments from public knowledge. They had reached agreements with the farmers who lived near their field outside Dayton, and with the local newspapers, that no notice should be taken of their flights. But finally one of their flights attracted so much attention that a score of men ap-

peared with cameras, and the Wrights decided that it was time to stop their experiments. They dismantled their machines, made public statements of what they had accomplished, and started to negotiate with various governments for the purchase of their aeroplanes for use in war.

In December, 1907, the Signal Corps of the United States army invited proposals for furnishing a "heavier than air flying machine." The Wrights submitted a bid, proposing to deliver a machine that would meet the specifications for $25,000. Their offer, with those of two others, was accepted. By now their names and something of what they had accomplished were very generally known, and when they began the preliminary tests of their machines at their old grounds at Kitty Hawk, near Kill Devil Hills, a legion of reporters was on hand. The Wrights still tried to preserve as much secrecy as possible, and the newspaper men to furnish as much publicity. The flights could not be concealed and the trials were announced as thoroughly satisfactory. On May 10, 1908, ten ascensions in the government airship were made, the longest being over a mile and a half. On succeeding days longer flights were made, one of two miles at a speed of forty-six miles an hour. Orville Wright made a flight with a passenger on board, and a little later Wilbur flew eight miles, at a rate of forty-five miles an hour. The reporters assured the world that the Wrights had proved the success of the "heavier than air" machine. As one of them wrote, "Then, bedraggled and very sunburned they tramped up to the little weather bureau and in-

formed the world, waiting on the other side of various sounds and continents and oceans, that it was all right, the rumors true, and there was no doubt that a man could fly."

Kitty Hawk, the place the Wrights had chosen because the Weather Bureau had told them the winds were strongest and steadiest there, now became one of the chief foci of the world's attention. The Wrights, still quiet and unassuming, suddenly jumped into fame. The public could not understand how these two men, bicycle-makers of Dayton, had learned so much about airships. They did not appreciate that the brothers had mastered every detail of flight long before, that they had learned the fundamental principles of soaring and floating, diving and rising, circling and gliding, before they attached the first motor to their planes. They had been far more thorough and more resourceful than those Europeans who had for some time experimented with aviation. Henri Farman, who had caused a sensation in Europe by flying a kilometer (five-eighths of a mile) over a circular course on January 13, 1908, came to this country, and heard what the United States government was requiring in the tests. "I have done some flying," said he, "but I do not try to do what your inventors must do at Fort Myer. I never fly in winds. Once I had a spill in France when I attempted it."

The government trials were held at Fort Myer, outside Washington. Here the Wrights took their machines when they were satisfied that they were in shape for the tests. Mr. Augustus Post, secretary of the

Aero Club of America, has graphically described in *The World's Work* for October, 1909, his impression of Orville Wright's flying in 1908. He says that Mr. Wright and he left Washington about six o'clock on a clear, still morning, bound for the flying field. "The conditions for flight were perfect," he continues. "Mr. Taylor, Mr. Wright's mechanic, got out the machine and it was placed on the starting-rail. The weights were raised, and Mr. Wright took his place. None of us expected anything more than a short flight down the field, with possibly a circle. The machine was released, and away he went, rising higher and higher, circling when he came to the end of the field and continuing round. I had taken the time of starting and marked on the back of an envelope each circle of the field. From a position of strained attention and fixed gaze, Mr. Wright gradually became more confident and comfortable; round and round he went for fully twenty minutes, and then we began to realize that something wonderful was taking place. Thirty minutes passed; we could hardly believe it. Mr. Taylor came up and said: 'Don't make a motion; if you do, he'll come down'; and we all stood like statues, watching the flying man, every nerve as tense in our bodies as though we were running the machine ourselves. Mark after mark I made on the back of the old envelope—so many that I had lost track of the number; it seemed an age since the machine started, and it appeared to be fixed in the sky. We were impressed that it could circle on forever, or sail like a bird over the country, so positive and assuring and complete

was this demonstration. We knew that the problem of flight by an aeroplane had been solved."

An accident caused the flights to be suspended for a time, but a year later the Wrights were ready for the official endurance test, a flight of one hour, carrying a passenger. President Taft and a great audience were present. Lieutenant Lahm was the passenger. Signal Corps men raised the weight and fastened the end of the starting rope to the aeroplane. Wilbur Wright, at the rear, turned the propellers and started the motor. Orville Wright adjusted the spark, and took his seat. He grasped the levers, spoke a few words of instruction to his passenger, seated beside him, and gave the word to release the machine. It glided down the track, gathering speed until it left the rails. Then the forward planes rose, and the plane soared into the air, flying swiftly. It circled around and around, each circle taking about one minute. For the first ten minutes the motor did not move smoothly, but after that it settled to perfection. The great audience, watches in hand, kept their eyes on the airship. The hour mark was passed, and there were wild shouts of applause and encouragement. Then the plane broke the world's record of one hour, nine minutes, and forty seconds, that Wilbur Wright had made earlier in the year. Wilbur Wright led in a cheer to those circling above. Then the airship began to descend, taking the circles easily, and finally skimming down to the ground. The motor was shut off, and the test was ended, the machine having flown for one hour, twelve minutes, and forty seconds. President Taft crossed

The Wright Brothers' Airship

WILBUR WRIGHT
ORVILLE WRIGHT

CABLE ADDRESS:
WRIGHTS, DAYTON

WRIGHT BROTHERS
1127 W. THIRD STREET
DAYTON, OHIO

July 22, 1911.

George W. Jacobs & Co.,

Philadelphia.

Gentlemen:-

Replying to yours of June 26th we are herewith enclosing a photograph of our first flight made at Kitty Hawk, North Carolina, on December 17, 1903.

Yours truly,

Wright Brothers

the field and shook Orville Wright's hand. "I am glad to congratulate you on your achievement," said he; "you came down as gracefully and as much like a bird as you went up. I hope your passenger behaved himself and did not talk to the motorman. It was a wonderful performance; I would not have missed it." Then he turned to shake hands with Wilbur Wright. "Your brother has broken your record." "Yes," said the other, smiling, "but it's all in the family."

Lieutenant Lahm said, "The machine was under perfect control at all times. He apparently had given no conscious thought either to his hands or to the levers. His actions all seemed involuntary. It had hardly started on one of its dips before his hands were moved in the proper direction to restore the balance. It seemed impossible for anything to go wrong. I never knew an hour to pass so quickly as that one up in the air. The first half seemed like ten minutes, and the second scarcely longer. I hardly felt the vibrations of the engine, but at first the rising and dipping were hard to get used to. The only disagreeable sensation I experienced was a deafness from the whirring motor. Sometimes the undulating movement was noticeable, but that was all. The sensation of riding the air in an aeroplane is indescribable."

The speed test came on the day following the endurance flight. This was to be made over a measured course of five miles from Fort Myer to Alexandria, and back, making a total flight of ten miles over trees, railroads, and rough country. Aviators declared this

a more difficult course than the crossing of the English Channel, owing to the great rises and drops of the land, which made it almost impossible to maintain a level course. Speed was a very important factor in the government's specifications for a successful airship, and the price to be paid depended on this, which had been calculated to be forty miles an hour. The government was to pay the Wrights $25,000 for the airship, and a bonus of ten per cent., or $2,500, for every mile made above the forty. For every mile less, to the minimum limit of thirty-six miles an hour, the government was to deduct the same percentage.

The machine that was making these tests was very similar to the one that had been used at Fort Myer the year before. The amount of supporting surface had been reduced by about eighty square feet, and a change had been made in the lever that turned the rudder and controlled the equilibrating device. This had originally consisted of two levers, placed side by side. Now the top of one lever was jointed, so that a sideways movement of the wrist was sufficient to move the rudder for steering in the horizontal plane. Simultaneously the lever could be pushed forward and pulled back to lift or lower the opposite tips of the wings. In this way one hand could control both the steering and the balancing of the planes.

In spite of the fact that the wind conditions were not exactly as he wished Orville Wright decided to make the flight for speed on that day. He made a good ascension, carrying Lieutenant Benjamin D. Foulois with him as passenger. Twice he circled the field in

order to get up speed and reach sufficient elevation. Then, amid cheers of encouragement from the immense throng that was watching, he turned sharply past the starting-tower and flew between the flags that marked the starting-line. Two captive balloons had been floated to show the course and also to give an indication of the proper altitude to maintain. The wind tended to carry the aeroplane to the east, but Orville Wright was able to hold it on a fairly even course, and to reach the balloon at Shuter's Hill that marked the turning point. Here the official time was taken by officers of the Signal Corps. On the return the airship met with strong downward currents of air that bore it groundward until it was hidden by the tops of trees. Mr. Wright said afterward, "I had to climb like forty all the way back." But he managed to send his aeroplane higher and higher, and to bring it back over the heads of the crowds at the finish line. There it swept about in a circle, and landed easily near the aeroplane shed. What aeronautical authorities declared to be the greatest feat in the history of aviation had been successfully accomplished. The elapsed time of the flight was fourteen minutes and forty-two seconds, which meant that the airship had attained a speed of a little more than forty-two miles an hour. The conditions of the Wrights' contract with the government had been in every respect more than fulfilled.

The Wrights carried Europe by storm, being received there with even greater acclamations than in America. The French, as a nation, had for some time been more interested in aviation than any other people.

France was the home of Montgolfier, Santos-Dumont, and Farman. At first France looked with incredulity and suspicion on the Wrights' claims. The French papers accused them of playing *le bluff*, and said that "they argued a great deal and experimented very little," which, as a matter of fact, was exactly the opposite of the Wrights' whole history. But as soon as Wilbur Wright showed what he could actually do, all this changed, and the French could not say enough that was good about him. Delagrange, his nearest competitor, acknowledged frankly that Wilbur Wright was his superior as an aviator. But he could not understand the American's quiet methods, and plan of pursuing his own way regardless of public opinion. He found that Wilbur Wright actually preferred to fly without an audience, and thought nothing of disappointing the crowds that gathered to watch him. On one such occasion, when Wilbur Wright found the weather conditions unsatisfactory, he declined to fly. "If it had been I," said Delagrange, "I would have made a flight if I had been likely to smash up at three hundred meters rather than disappoint those ten thousand people."

This novel charm of simplicity caught the French fancy. The Wrights wanted to do everything for themselves. At Kitty Hawk they had lived in a small shack, and cooked their own meals. Wilbur Wright had a similar shack built on his flying-field in France, and planned to do his own cooking. But this was too extreme for the French mind. When he went to his shack he found a native cook installed there, and had to submit to the hospitality of his hosts.

The Wrights were organizing companies in the different countries of Europe, and wanted to attend strictly to their business. But wherever they went they were fêted. They met the French President, the Kaiser, the King of England, and the King of Spain, and they were dined and publicly honored in all the great capitals. Germany turned from its native hero, Count Zeppelin, to admire them. But everywhere they kept that same quiet tone. They showed that they cared nothing to perform hazardous feats simply because of the hazard, nor to establish records. Wilbur Wright was asked if he would not try for the prize offered to the first man to fly across the English Channel. He said he would not at that time, because it "would be risky and would not prove anything more than a journey over land." And the public knew that this was sensible caution, and not lack of courage.

Daring aviators sprang into fame at once. Most of these built their machines according to their individual ideas, and there was a great trying-out of different patterns. Blériot, a Frenchman, flew across the English Channel in a monoplane in thirty-eight minutes. Instantly he became the French idol. When he reached Paris at five in the morning an enormous crowd welcomed him, and the cries of "Vive Blériot!" could be heard for squares. He was dined at the Hôtel de Ville, given the Legion of Honor, and money was subscribed for a monument to mark the place near Calais where he commenced his flight. Shortly after Roger Sommer rose in the country outside Paris on a moonlight night, and flew for two hours, twenty-seven

minutes, and fifteen seconds, the longest flight made to that time. The world recognized that the actual invention of the airship was one of the greatest achievements of the ages. Said the *London Times*, "It is no wonder that there should be great enthusiasm in France over the cross-Channel flight of M. Blériot, and that the French papers should talk of nothing else. Further enthusiasm will doubtless greet the gallant attempt, which was all but successful, of M. Latham yesterday, to repeat the achievement. Since the discovery of the New World no material event has happened on this earth so impressive to the imagination as the conquest of the air which is now half achieved. Indeed, the conquest of the air is likely to be more vast and bewildering in its results than even the discovery of the New World, and one is inclined to wonder that men should take it as calmly as they do."

A great aviation week was held at Rheims, and almost all the world's famous aviators, except the Wrights, were there. Control of the airships was shown to a remarkable degree. On one of the preparatory days three heavier than air machines were manœuvring in the great aerodrome at the same time. They were flying at high speed, when suddenly Glenn H. Curtiss, an American, saw an Antoinette aeroplane approaching him at right angles, and flying upon the same level. Instantly he elevated the planes of his machine, and his aeroplane obeyed his touch, shot upward, and flew over the Antoinette. There was great applause from those who had been watching him.

The manœuvre showed how easily the airships were controlled.

Germany meantime was intensely interested in Count Zeppelin's dirigible balloons, which, although as long as a battle-ship, had flown with great success. The German government paid $1,250,000 into the Zeppelin fund for experiments, and contributed a large sum in addition to the maintenance of a balloon corps. The German people showed themselves as proud of Count Zeppelin as the French were of Blériot, and the Americans of the Wrights.

The aviation week at Rheims was followed by other great airship meets in other countries. The Hudson-Fulton Celebration in New York in the autumn of 1909 was the occasion of new records in flying, and served to awaken Americans to a more intense interest in navigation of the air. That meeting was followed by others in all parts of the United States, and competitions for height and city-to-city flights became matters of weekly occurrence. Yet America has not so far reached the intense enthusiasm over flying that fills the lands of Europe.

The airship is on the market, ready to be purchased by whomsoever will pay the price. The London daily papers advertise an agency that will supply buyers with either the Blériot monoplane of the type Calais-Dover, the Latham or Antoinette monoplane, or the Wright and Voisin biplanes. Moreover the art of handling the aeroplane does not seem unusually difficult to master, provided one has the taste for it. Roger Sommer first sat in an airship on July 3d, yet

on August 7th following he made a world's record flight outside Paris. "It is easier to learn to fly than it is to walk," Wilbur Wright has said.

The only American machines besides the Wrights' biplanes which have made a name for themselves are the Curtiss biplanes. Mr. Curtiss is one of the most daring aviators in the world, and his flight down the Hudson River attracted the widest attention. But there are questions as to whether his aeroplanes do not infringe on certain patent claims of the Wrights, and his flight was made under a bond that should protect the Wrights in case it proved later that his biplane did infringe on their title. Here it should be said that the Wrights are as excellent business men as they are inventors, and intend to receive due compensation for their years of work. At one time they offered to sell their invention outright for $100,000, but since then their patents have been upheld by the courts, and those patents cover a very large area of the field of airship manufacture. The American market is largely in their hands.

Every year lighter and lighter gas-engines are being made, and this means that the surplus carrying power of the aeroplane can be increased. Fuel can be carried for flights of greater and greater distances, and rapid increases of speed can be attained. With improvements in safety there seems no limit to the possibilities of flight. So far a long train of casualties has marked the airship's progress. This was inevitable when men came to imitate the birds, and trust themselves to the fickle currents of the air. But many aviators have

been drawn from a reckless class, and many accidents have been due to a desire to thrill an audience rather than to learn more about the laws of flight. The Wrights have held to the wise course. They care nothing for spectacular performances or establishing new records for their own glory. Their work is in the shops, devising improvements that will make the airship safer and better fitted for commercial uses. They are men of remarkable balance, and it was their quality of unremitting care that made them the wonder of Europe, used above all things else to the dramatic in men's flights through air.

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